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Investigations at the Cryogenic Laboratory at Leyden*

By C. A. Crommelin,
Conservator of the Physical Laboratory of the University of Leyden.

THOSE who have read items concerning the question of low temperatures know that Prof. Kammerlingh Onnes has built up at Leyden an institution unique in the world, the Cryogenic Laboratory (*Κρυος*, cold), where not only are obtained the very lowest temperatures, but where it is possible to study the properties of bodies at such temperatures.

To do this, it is necessary to understand the liquefaction of gas, and to realize that this liquefaction is only a means to an end. It does not suffice to produce a few drops, more or less fugitive, of a gas, said to be permanent, and to prove thereby that it can be made liquid, but rather to obtain it in great liquid masses in static conditions and to manipulate it conveniently in such fashion as to determine the constants of temperature of spaces relatively large, and to do all this at temperatures increasingly low. Such results can be obtained only by the rigorous application of a uniform method which is applicable to the working of powerful and complicated machines and apparatus, but which, also, must be capable of furnishing results of great precision. Thus the unique laboratory of Leyden gives to the uninformed visitor the appearance of a manufactory.

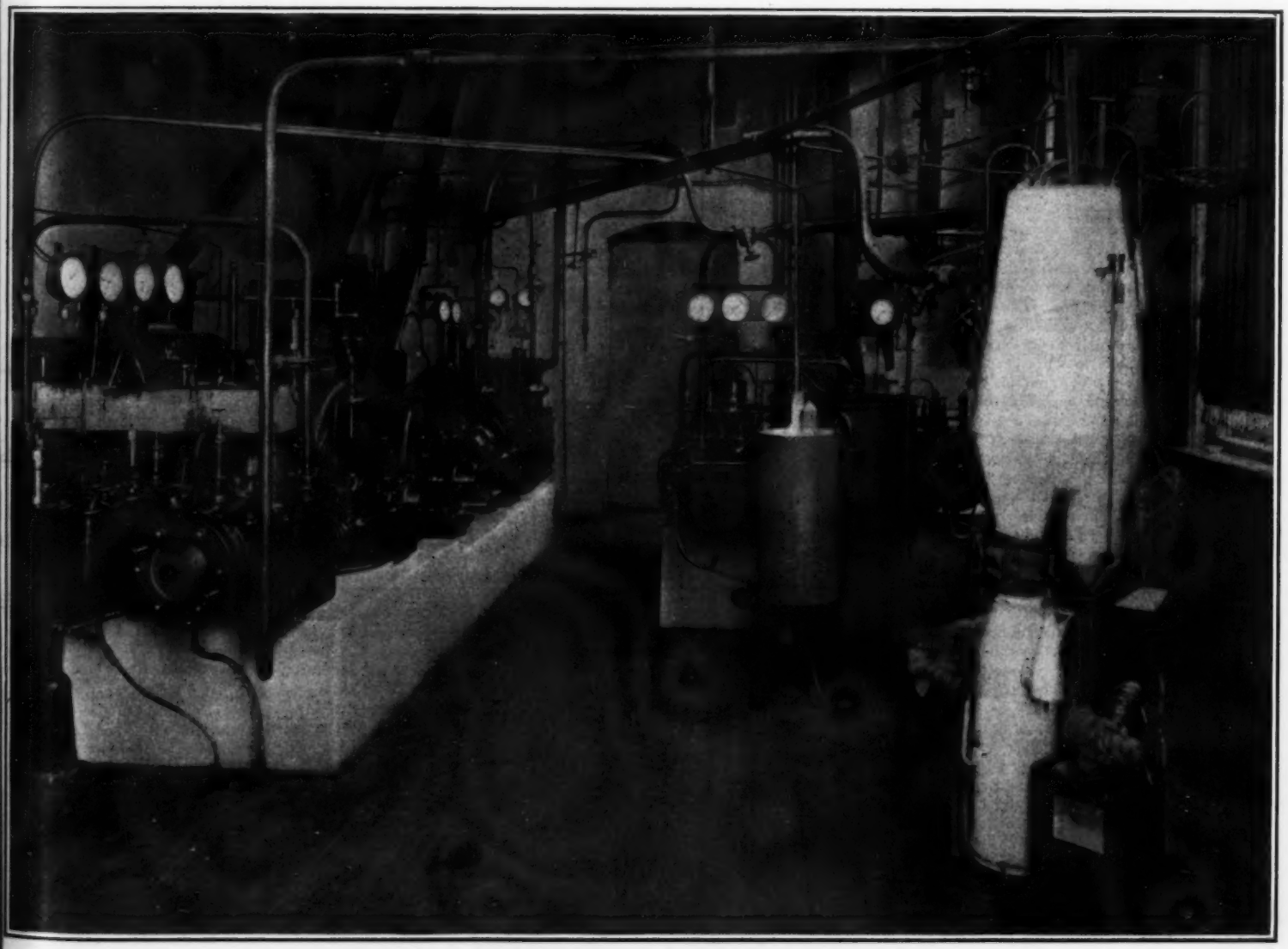
It is indeed a factory which it is necessary to operate with a corps of scientists, preparers, and skilled mechanicians, working together throughout a dozen consecutive hours if one would make a series of researches at the very low temperatures which the liquefaction of hydrogen and of helium demand.

Without doubt it is on account of the necessary slowness of procedure that Prof. Onnes was not the first to liquefy hydrogen, but he has surely contributed to that success with helium, the most difficult of all the gases to liquefy, and the laboratory at Leyden is to-day the only one in the world where such results have been obtained. It is also the only one to which the scientists of the entire world can come to study the questions which interest them concerning low temperatures. In this respect it offers the greatest hospitality and the most splendid facilities. A programme is established in consultation with Prof. Onnes, who, aided by his regular fellow workers, outlines the task; the apparatus necessary for the experiment is prepared, and then in collaboration with the visiting scientist the experiment is carried to its finish.

In what is to follow nothing will be said concerning the mere liquefaction of gas nor of the personal work of Prof. Onnes, who succeeded in liquefying helium in 1908, nor of the technical outfit of the Leyden laboratory. Nor is anything said about the cryostats for liquid helium, which through their excellent planning and construction have made the measures of this gas possible. Instead this article will sketch the principal experiments and researches which have been conducted with low temperatures these past few years. As may be seen, these researches constitute one of the most interesting chapters in the history of science, for they all treat of the constitution of matter, a question that at this moment is in the minds of all the scientists.

Why are these investigations of low temperatures so interesting? The reply to this question is not to be given in a single word. Different researches have often a character of their own. The desire to study the conditions of various substances under temperatures as far apart as possible, and to support the hypothesis of van der Waals by experimental results, was without doubt one of the principal motives of Prof. Onnes in establishing his own special laboratory. The matter can be considered in a more general way, however. Most of the properties of bodies depend more or less on molecular activity induced by thermal conditions. But this activity often has the effect of obscuring the phenomena. One may expect that as the temperatures become lower and lower, and the activity weaker and weaker, the phenomena will present themselves more clearly and well defined. It is this general consideration that is the foundation for the hope that the investigations of Prof. Onnes will add much to our knowledge of molecules and atoms, and this, at a time when but few even among the scientific men fully realize the importance of measures at low temperatures. One cannot help, therefore, admiring the far-sightedness of this observer when it is evident that an entire section of modern physics depends on the very low temperatures that he is studying.

* Translated from a paper in *Le Génie Civil.*



The hydrogen-liquefying plant of the University of Leyden.

In the left foreground is the hydrogen compressor; in the middle ground, air pump for boiling liquid air (preliminary hydrogen refrigerant) under reduced pressure; in the center, two hydrogen compressors; at the right, liquefier yielding 10 to 12 liters per hour.

A. THERMODYNAMIC RESEARCHES.

The researches in thermodynamics, which for a long time constituted the entire work accomplished at the Leyden laboratory, remain to-day an important part of its duties. In the studies of gas, it is above all the monatomic gases that have especial interest on account of the simplicity of their structure. Among them helium occupies the first place. The determination of certain isotherms, notably in the temperatures of liquid hydrogen, make it possible to estimate the constant, *a*, of van der Waals and critical data; estimates which together with the law of corresponding states guided Onnes in the construction of his appartus for liquefying helium. A short time after its liquefaction (July 10th, 1908), Prof. Onnes tried to obtain solid helium, but without success. Even under a pressure of 0.2 millimeter of mercury, the temperature being lowered to 1.15 deg. Kelvin (the lowest ever yet obtained), helium remained liquid without even showing a trace of viscosity.

Researches in this direction have not been carried further, for there were more important things to do. Prof. Onnes next determined the vapor tensions, critical data (5.25 deg. Kelvin and 2.75 atmospheres) of helium, and the density of its liquid, and of the saturated vapor at different temperatures. He observed a curious anomaly: the density of the liquid is at its maximum in the neighborhood of 2.2 deg. Kelvin. On this point Prof. Onnes has made theoretical deductions that are very interesting.

With reference to argon, he has determined an extended range of isotherms, its critical data (— 122.44 deg. Cent. and 48 atmospheres), the triple point (— 189.30 deg. Cent. and 51.57 centimeters of mercury), the normal boiling point (— 185.84 deg. Cent.), the tensions of solid, liquid, and vapor to — 216 deg. Cent. and the densities of the liquid and saturated vapor. These are his latest determinations, items very important for the industry of the distillation of liquid air, and which shows that argon obeys the law of rectilinear diameters of Cailletet and Mathias. Further, it is of interest to know that argon is thus far the only substance with low critical temperature for which the different thermodynamic data are known through a region of temperatures quite extended. Among these the isotherms in the neighborhood of the critical point are of first consequence. By means of these researches it has been possible to compute a number of important constants for argon, for example, the heat of its vaporization, the values of $\left(\frac{dp}{dT}\right)_v$, from which one may estimate the very slight variation in function of the temperature of the "internal pressure" of Amagat, that is to say, $\left[T\left(\frac{dp}{dT}\right)_v - p\right]v^2$, etc.

The researches on neon, due to Georges Claude, offer considerable difficulty from the experimental point of view, because the critical temperature of this substance lies in a region so hard to reach between — 217 deg. Cent. (liquid oxygen under a pressure of 2 millimeters of mercury) and — 253 deg. Cent. (liquid hydrogen under atmospheric pressure). A provisional determination of the critical pressure (30 atmospheres) has been made, and apparatus for the experiments is under construction, so that results may presently be expected in the matter.

In the work with diatomic gases there should be mentioned the establishment of a series of isotherms for hydrogen above the critical point (from + 100 deg. Cent. to — 217 deg. Cent.) at pressures relatively high, and below this point (at temperatures of liquid hydrogen) at low pressures. By means of this group of isotherms there has been calculated with reasonable precision the corrections for an international hydrogen thermometer (of constant volume at 1,000 millimeters pressure at 0 deg. Cent.) to make it accord with the absolute thermodynamic scale of Kelvin. These determinations are of extreme consequence in the thermometry of precision at low temperatures. The same computations have already been made for a helium thermometer, and a direct comparison of the two thermometers, recently accomplished, confirms the results obtained to within 0.02 degree.

The densities of hydrogen, liquid and solid, and at different temperatures, have already been determined, as well as the measurements of contraction which ensues on solidification; also the vapor tension at atmospheric pressure and below it (normal boiling point — 252.76 deg. Cent.; triple point, — 259.14 deg. Cent. at 5.07 centimeters of mercury), facts which are very important for thermometry, since in measuring vapor tension with a precision now easy to secure one passes the bath constant (0.01 degree), so that an apparatus to determine the vapor tensions of hydrogen appears to be the most convenient thermometer for the temperatures of liquid hydrogen.

For oxygen, as for argon, the curves have been determined for the densities of the liquid and the saturated vapor. Here it is found that the substance follows the law of mean densities and the triple point is determined (— 218.4 deg. Cent. and 1.5 millimeters of mercury). For nitrogen and oxygen, measures have been made of the critical data as well as a number of vapor tensions. Researches on the "diameter" of nitrogen are actually in course of preparation.

Work has also been done on the easily liquefiable gases. At several places, and especially at the International Congress of Refrigeration, at Paris in 1908 and Vienna in 1911, the representatives of the industries of cold drew attention to the advantages there would be in new and better determinations of certain thermodynamic constants of the gases employed in refrigerating machines, particularly those of ammonia and methylchloride. Since such researches seemed likely to lead to important increases in scientific knowledge, Prof. Onnes decided to make the needed determinations in the laboratory at Leyden. He began by the deep discussion of the constants already set forth by other investigators, and also made plans to determine between such results when they were not in accord, and finally to fill the considerable gaps which existed in the series.

He found that it was necessary:

1. For ammonia, to determine the isotherms between + 20 deg. Cent. and + 100 deg. Cent. and between 1 and 16 atmospheres; the isotherms of the vapor at 0 deg. Cent. at low pressures; and the vapor tensions at high pressures (up to 16 atmospheres) in order to choose between the two non-concordant series of Regnault; and at low pressures (1 atmosphere) to decide between disagreeing series of Brill and Davies. The knowledge of the isotherms combined with that of the vapor tensions served for the computation of the densities of the saturated vapor, the more valuable since direct determinations in the apparatus that have served for argon and oxygen offered experimental difficulties.

2. For methylchloride it was essential to determine an isotherm at + 20 deg. Cent., to choose between the series of Kuenen and Leduc on the one hand and those of Brinckman and Baumé on the other, and to secure a group of isotherms at low temperatures and pressures. Then it was necessary to determine a certain number of vapor tensions to check the values of Regnault. By combining these new results with those already at hand it became possible to calculate the densities of the saturated vapor as well as the heat of vaporization at different temperatures. In this way it became possible to determine for the two liquids the specific heats for liquid and vapor and thereby to construct the entropy diagrams of Mollier.

At the present writing all the measurements here spoken of, excepting the calorimetric ones, have been determined with the greatest of care, and a portion of the results, the plan of investigation and the discussion of previous measures, have already been published in a report presented to the Third International Congress of Refrigeration at Chicago, September, 1913. The other reports will appear very soon. It is but fair to predict that these results will be of fundamental importance to science and to the industries engaged in the production and use of cold.

Especial interest attaches to the measurements of the vapor tensions of carbonic acid at low temperatures (from — 135 deg. Cent. to — 183 deg. Cent.) where the pressure is so weak that the manometer is necessary to measure them, or even the Knudsen manometer, and expression is in baries (1 barie = 0.000,749,586 millimeter of mercury). Determinations of this character have especial importance, for they connect themselves with Nernst's hypothesis of heat, whereby this scientist has deduced the formulas of vapor tensions.

In regard to gases easily liquefiable one cannot omit the researches relative to butane, which has recently been investigated in various ways, and for which, among other things, there have been determined the vapor tensions, the densities of the liquid, and the vapor saturation at different temperatures.

B. ELECTRICAL RESEARCHES.

The researches relative to electricity also form a chapter of fundamental importance among the many works at Leyden. In the course of the researches the study of resistances of metals at low temperatures has led Prof. Onnes to a very interesting discovery. The general study of resistances of metals has been already the subject of numberless investigations. Basing his conclusions on the results obtained by himself and those of Dewar, and giving attention to the theory of electrons in metals, Prof. Onnes believes that resistance reaches a minimum at a very low temperature, to increase very rapidly below this degree and become infinitely great when absolute zero is touched. This conception is reached through considering electrons as having motion between the molecules of a metal as an "electronic vapor" which, at extreme temperature, condenses in a solid state on the molecules. The carriers of electricity being reduced to immobility, the passage of electricity becomes impossible. If, on the contrary, the electrons are considered an "electronic gas," the conclusion must be that in reducing the temperature the resistance must be lowered also. Of the two conceptions, the first would seem to be the more plausible.

In beginning his measurements of liquid helium, Prof. Onnes tried to find in this region of low temperatures that of the lowest resistance. But he observed a curious phenomenon; the resistance of gold and platinum became constant in the whole region of liquid helium. He thought that perhaps metallic impurities might be the cause of this residual resistance and that it ought to disappear at absolute zero. He hastened, as well as one can hasten in such delicate and difficult work, to repeat the experiment with mercury, a metal that can be obtained in almost absolute purity. The results were altogether unexpected; for the resistance decreased regularly till in the vicinity of 4.20 deg. Kelvin, that is to say, a little above the boiling point of helium, then fell suddenly to a value less than one millionth of that at the point of congelation, and fell immediately afterward to a billionth of that value when the lowest temperature obtainable was reached.

Tin and lead present the same phenomena, the former maintaining its regular fall to 3.8 deg. Kelvin, and lead to about 6 deg. Kelvin. The resistances of the three metals become in their new state what Prof. Onnes has been pleased to term "superconductive," so small that it has not been possible to measure with precision. But one can gain a notion of the minuteness from the fact that the Leyden scientist has been able to pass through the mercury, electricity, with a current-density of 12 amperes to the square millimeter without measurable manifestation of heat.[1]

Now what does this consideration of these strange phenomena teach us? It appears at the outset that the hypothesis of "electronic vapor" must be abandoned. Prof. Onnes had then the idea of applying Planck's hypothesis of oscillators to the electronic hypothesis of metals. In his quanta hypothesis Planck has introduced oscillators of which the mean energy disappears at a temperature clearly below absolute zero. If we now consider the oscillators as obstacles to the movements of electrons, we can understand that somewhat below absolute zero, the oscillators being in repose, and the electrons having now no opposition, the passage of electricity is practically free. When one computes the mean free path of the electrons at this temperature the result is in values of the order of a meter.

Space will not permit of the notice of very interesting applications that befall superconductive metals in intense magnetic fields, nor the considerations of Prof. Onnes on various other theoretical questions related to superconductivity. But something must be said of researches relative to the Hall phenomenon (when a magnet acts on a conductor it affects also the current flowing through this conductor), and the change of resistance in the magnetic field, which investigations are the subjects of a number of memoirs emphasizing the theoretical side of the researches. The two phenomena have been measured from ordinary temperatures to those of the liquefying of hydrogen for bismuth, gold, silver, copper, palladium, mercury, nickel, and iron. And besides, Hall's phenomenon has been observed with a goodly number of gold-silver alloys.

C. RESEARCHES ON RADIOACTIVITY.

Great interest attaches to investigations of the effect of low temperatures on the radiations of radium. Such work has been done at Leyden by Madame Curie and Prof. Onnes. The apparatus and methods, interesting as they are, must be passed over to state the results, namely, that in cooling radium to — 253 deg. Cent. it has not been possible to note any change in the intensity of the gamma rays, even with a precision of measurement of 1/1,000.

D. RESEARCHES ON MAGNETISM.

The study of magnetism has entered into a new phase since Langevin conceived the idea of developing an electronic theory of paramagnetism and of diamagnetism, and Weiss has extended his hypotheses to the ferro-magnetic phenomena, introducing the idea of a molecular field, and has discovered the elementary magnetic moment, the "magneton."

Let us omit here the phenomena of para and ferromagnetism. According to Langevin, the molecules of paramagnetic substances contain elementary magnets of constant moments. Molecular agitation by heat opposes itself to the uniform orientation of the molecules, and, admitting that the rotational energy of the molecules is proportional to the absolute temperature, it results from the theory of Langevin that the specific suscep-

[1] Since this was written, Prof. Onnes has been able to prove that at a temperature of nearly absolute zero no resistance whatever is offered to a current in a conductor. Prof. Onnes's report on this matter appears on another page in this issue. — Editor of SCIENTIFIC AMERICAN SUPPLEMENT.

tibility (attraction per gramme for a field equal to unity) is inversely proportional to the absolute temperature. This is the law of Pierre Curie applied to paramagnetism.

Weiss's molecular field is the name given to certain mutual actions of magnetic molecules, the origin of which is not known, but which are much stronger than any exterior field practicable with electromagnets which present saturation phenomena. The study of saturation is particularly interesting at very low temperatures.

It is for this reason that Prof. Onnes, in collaboration with Weiss, has determined magnetization to saturation at the temperature of liquid hydrogen for iron, nickel, cabolt, and magnetite. The results obtained have furnished to Weiss all that was lacking for the discovery of the magneton and for the computation of its size. For by dividing the magnetism-saturation by the number of molecules per unit-volume one obtains an elementary magnetic moment. Weiss has thus been able to show that all the molecular moments are multiples of an elementary moment, that is to say, of magnetons. The elementary magnet or iron contains eleven magnetons, and that of nickel three.

It will be understood from what precedes that the researches on the exceptions to the law of Curie are of high importance for the hypothesis of Langevin and for the magneton of Weiss. It is possible to compute the number of magnetons in any substance after a determination of its susceptibility to a given temperature, if the substance obeys rigorously the law of Curie. But this is often not the case.

Oxygen, the only gas which presents a fairly large paramagnetism, and already studied by Curie at high temperatures and pressures, is particularly interesting because it can be observed under the three conditions, solid, liquid, and gaseous. In the gaseous state it obeys the law of Curie, although as liquid or solid it presents considerable departures therefrom. An interesting fact is that in diluting oxygen with liquid nitrogen, a body nearly indifferent from the magnetic point of view, it has been found that the specific susceptibility of liquid oxygen is not only a function of the temperature, but also of the number of molecules of oxygen contained in a unit of volume.

The principal results found thus far with reference to other substances are that crystallized sulphate or gadolinium follows the law of Curie down to — 259 deg. Cent. and similarly, the phenomena of saturation in ferric sulphate have been observed to low temperatures. It would appear, therefore, as if there had been found here a substance paramagnetic at ordinary temperatures and ferromagnetic at the temperature of liquid hydrogen.

Although it has been necessary to pass over a number of matters, the reader will have a fair idea of the different researches undertaken at the Cryogenic Laboratory at Leyden, and the theoretical questions there considered. When one realizes that Prof. Onnes has taken the initiative in these researches, that he is the intellectual father of the greater part of the investigations here described, one will rejoice with all those who have worked beside him in the distinction that has come to him from the Academy of Stockholm, distinction which, in addition, is sanctioned by the whole scientific world.

On the Persistence in Superconductors of Electric Currents Without Electromotive Force*

By H. Kammerlingh Onnes

THE time of persistence of a current once established in a circuit, and then left to itself without electromotive force, is ordinarily extremely short, but for circuits in superconductors it can become so great that the current is practically permanent. This is the result of a computation based on data which the study of superconductors has furnished. I have just confirmed this conclusion by experiments which on their side lead to facts which may be reached by still another way. Let us review what has become known about the properties of superconductors.

In studying the resistances of metals at temperatures that one may obtain with liquid helium, I foresaw that the resistance of mercury would still be easy to measure at 4.25 deg. Kelvin, but would diminish so as to become negligible at 2 deg. Kelvin (— 271 deg. Cent.). Experiments have verified this prediction so far as low temperatures are concerned, but at the same time have brought to light the fact that the disappearance of the resistance is sudden. The mercury at the temperature of the fall, here termed critical temperature (4.19 deg. Kelvin), passes in a disconnected way into a new state that is characterized by an extreme mobility of electricity. It may be well to term this condition, in which it is possible to maintain currents without appreciable electromotive force, the state of superconductivity. Into a thin thread of mercury 1 meter long at 1.7 deg. Kelvin I have been able to pass a current of the current density of about 1,000 amperes per square millimeter without an appreciable difference of potential at the two ends (limit of precision being 0.03×10^{-6} volt) and without developing there, in consequence, any trace of heat.

On dividing the difference of potential limit by the current, I have come to an upper limit of what I have provisionally termed the "microresidual resistance" of the superconductor.

For the metallic thread of which I have just spoken, it is the billionth part of its resistance at ordinary temperatures. The condition of superconductivity is not limited by temperature alone; current density is also a factor. For each temperature there is a critical density, different probably for the different conductors, below which there is no appreciable difference in potential. Above this density, as has been shown by wearisome analyses, there is developed a resistance of the same nature as that which is established when one passes the critical temperature, which I have termed "ordinary resistance."

This ordinary resistance, extremely weak at first, gives way at the first appearance of the differences of potential. The increase in temperature by the Joulean heat which is disengaged presently invades the whole conductor, so that differences in potential of the two ends, so soon as they appear at all, grow very fast with further increase of the current.

The critical density is very small at temperatures below the critical temperature, but it becomes very considerable when one works at temperatures notably lower, so that one can charge a circuit at these temperatures with a fairly strong current without its losing its character of superconductivity. Such circuits approach the circuits without resistance that Webber has introduced in his explanation of diamagnetism. With them it is possible to explore the vast field for experimentation to which the investigator is conducted by placing in the equations of electrodynamics a resistance infinitely small, or by admitting that the free course of the electrons is of the order of one meter. But the making of apparatus for experiments with mercury is difficult. It is fortunate, therefore, as was developed later, that tin and lead also become superconductors. The critical temperature of tin is 3.8 deg. Kelvin, and that of lead, probably 6 deg. Kelvin.

To study the application of superconductors to the production of intense fields—a problem of great difficulty on account of the disengagement of Joulean heat within very small spaces—I made a coil of 1,000 turns of lead wire, the section of the wire being 0.1 square millimeter, rolled into the thickness of 1 centimeter, and with a width of 1 centimeter. A current of about 0.8 ampere was passed into the coil without having had need of electromotive force to maintain it. There was no measurable development of heat. I had first considered provisionally the construction of an electromagnet of modest dimensions without iron, after Perrin, which would give a field of 100,000 gauss without developing a single joule. But here the investigation brought to light a new and highly interesting property of superconductors which makes such application impossible. The field, still inactive at values which were attained in our coil, as soon as one passes a certain critical field (1 kilogauss for lead at 1.8 deg. Kelvin) develops quickly enough the ordinary resistance in a superconductor, giving rise to heat due to the magnetic field. This critical field increases on passing below the critical temperature. It is important, therefore, when experimenting with a conductor that is exposed to a field (exterior or its own) to remain below the critical field.

Returning to the coil of lead wire at 1.8 deg. Kelvin, it is this which served me to demonstrate the persistence of currents without electromotive force in superconductors. Its coefficient of self-induction is 10^3 C.G.S. with a current of 0.6 ampere (one cannot go below 0.8 ampere, for there it has been found higher than the critical intensity); its electrokinetic energy is then considerable, to be exhausted but slowly so long as there is not introduced into the circuit an ordinary resistance, which, however small, would absorb it in a short time. The total flux of the coil in a field of 200 gauss, much below the critical field determined above, is 0.6×10^3 C.G.S., and suffices to establish a current of 0.6 ampere by induction.

The two ends of the circuit having been soldered together in the oxy-hydrogen flame—this by experiment being known to be a superconductive joint—the microresidual resistance of the coil was found to be less than one twenty-billionth of its resistance (736 ohms) at ordinary temperature. The time of persistence calculated by these elements is to be expressed in days.

Experiment has verified the computations. The coil inclosed in the cryostat was refrigerated in a field of 200 gauss from 0 deg. Cent. to 1.8 deg. Kelvin. In the superconductor circuit obtained in this way without current, a current giving it a paramagnetic moment developed itself when the field was moved away. The needle of a compass near the cryostat showed a strong disturbance when the coil was turned about a vertical axis. The coil acted like a permanent magnet, or rather a molecular current of Ampère. The moment measured by repeating its action on the compass with a coil of known current from previous tests indicated a current of from 0.4 to 0.6 ampere for hours in the superconducting coil. The precision of measurements under these extraordinary circumstances was not great. It did not permit of the measurement of any weakening. It has been possible only to indicate the higher limit. A decrease has been noted only at the beginning of an experiment and once again in connection with the return to a higher temperature. Leaving out these instances, as well as other peculiarities which demand later elucidation, it is possible to assert provisionally that the loss does not surpass 1 per cent an hour. In taking the coil from the temperature of liquid helium so that it could be raised above the critical temperature of lead, the phenomenon disappeared.

Control experiments were made by placing the plane of the coil parallel to the field. This gave unexpectedly an effect which was only about one eighth of the principal effect, and this was found again in experiments with the coil circuit open.

Further experiments have been tried with the coil in the first position and always refrigerated. A field smaller than the critical one was applied, and then, after some time, the field was withdrawn. The diamagnetic current resulting from the first operation was destroyed by that resulting from the second. There has been found an insignificant residue. Then a field capable of inducing twice the critical current was applied, and after a time, removed. The diamagnetic current of the first operation has been able to persist only when its intensity was reduced to the critical one. The second operation, after having nullified the persisting current, has produced on the disappearance of half the field which then remained a paramagnetic current about equal to that obtained in the previously described experiment. A very strong field applied in the same way has given the same result.

All these facts agree and leave no doubt about our having deduced properties belonging to superconductors. But it is interesting to have arrived at the superconductivity phenomena of lead refrigerated in helium in another way, an independent one, proving that the cause of the magnetic moment of the coil is indeed the current that circulates in it. To test this the two connections of a ballistic galvanometer were applied to the right and left of the soldered joint and close to it. Establishing the current in the coil as in the first experiment, and having placed the compass showing that the coil had a persisting moment, the joint was cut and the current observed to flow into the galvanometer (in which it was extinguished instantly), and at the same time the compass needle returned to a deviation corresponding to that moment which had been found in the experiment with the circuit of the open coil.

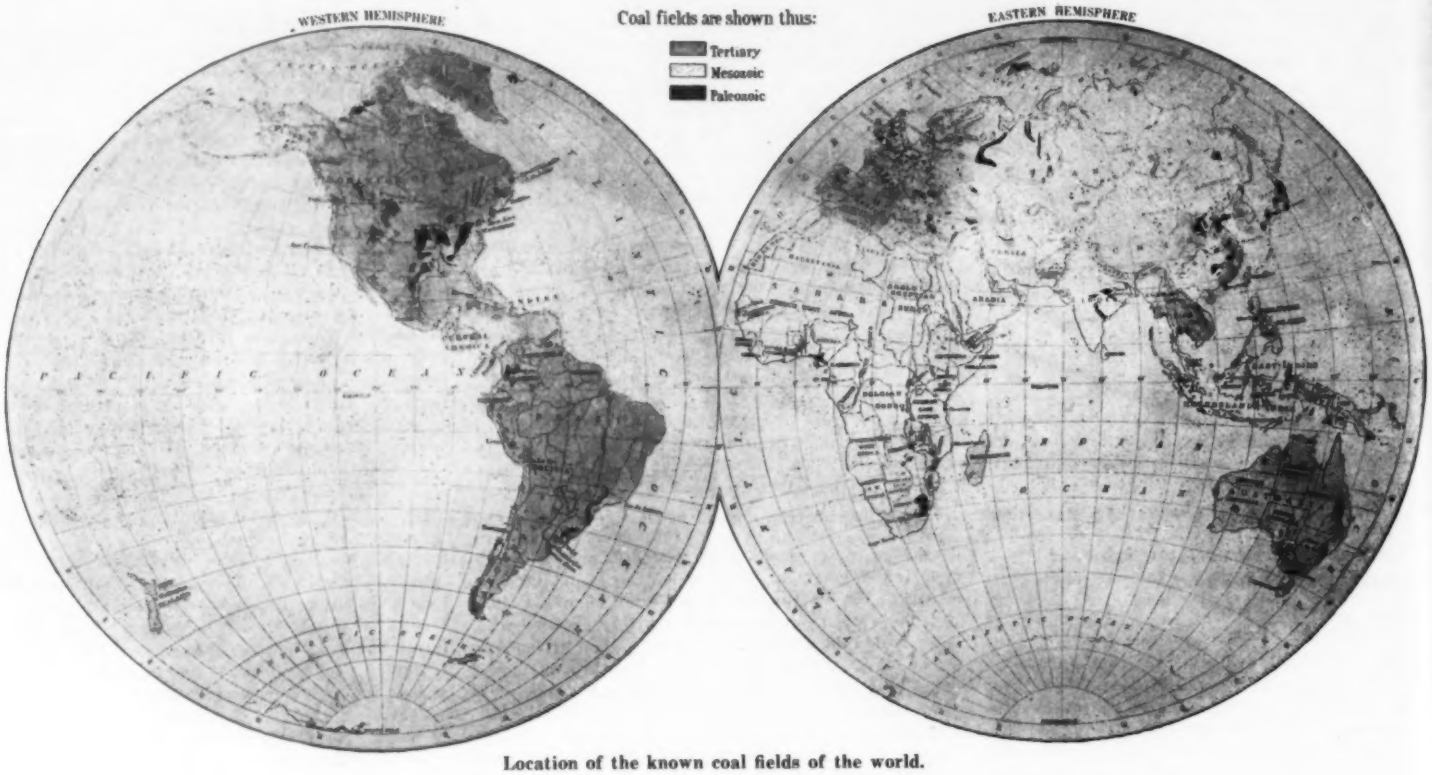
All this is suggestive of the idea of frictionless mechanics that Maxwell invented, completed to-day by the conception of electrons, which present themselves in very real fashion in these experiments. The electrons continue to circulate without electromotive force, and the rings, endowed with inertia, which in the hypothesis of Maxwell turn in the ether, continue to turn indefinitely. The smallest ordinary resistance introduced into this mechanism brings it most suddenly to a stop.

* A note presented by Prof. H. Kammerlingh Onnes to the Academy of Science through A. d'Arsonval at the meeting of June 29th.

An Automatic Mercury Pump

THE *Journ. de Physique* describes a mercury pump that differs from older ones of the same type in that the gases instead of being evacuated directly into the atmosphere are evacuated into a canal system connected with a column of water and, in place of the displacements of the mercury being produced by displacements of the receiver, they are produced by the fact that the latter is put in communication alternately and automatically with the atmosphere and with the column of water by the action of a suitable arrangement. Diagrams are given showing the connections of the parts, and the method of working, together with the rate at which the gases are removed, are dealt with in detail.

Twenty States have published reports of their woodusing industries.



Location of the known coal fields of the world.

Coal and Its By-Products—II*

How and of What Coal Was Formed, and Some Account of Its Utilization

By Louis Cleveland Jones, Ph.D.

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 2016, Page 118, August 22, 1914

NATURAL BY-PRODUCTS OF CARBONIZING ANCIENT VEGETATION RESIDUES.

SINCE commercial carbonizing of coal gives the benzene series of products, and not paraffines as existing in petroleum and natural gas, efforts have been made to explain the origin of natural gas and petroleum from animal remains, and Moissan has suggested the carbide theory. We believe, however, that the slow distillation of coal at low temperatures is a more logical explanation.[3]

Industrial experiments recently carried on in England upon low temperature distillation by the Coalite process, and more recently on coking coals at even lower temperatures, and *in vacuo*,[4] indicate that petroleum products identical with those found in nature are thus obtained.

In duplicating nature's conversion of bituminous coals to anthracite, the modern by-product oven, operating at a temperature of 1,000 deg. Cent. or more, does the work of ages in a day, producing coke the equivalent of natural anthracite, and, in place of natural gas and petroleum, illuminating gas and oils of the benzene series.

In the electric furnace we convert coke into graphite, and Moissan has converted graphite dissolved in cast iron into the diamond, the end of the series. But at these high temperatures, as stated before, the by-products are largely of the benzene series, while nature's by-products are of the methane series.

LOW TEMPERATURE CARBONIZING EXPERIMENTS.

Recently, therefore, in our laboratory at Syracuse, we have tried to determine the nature of the products at low temperatures, starting with the wood and going through the series to coke.

Our experiments are still incomplete, but some of the results are tabulated below. For example, wood, brown lignite, black lignite, Illinois coal, Kanawha gas coal, smokeless coal and anthracite were gradually heated until decomposition started and a small part of the gas was driven off. The results are calculated to the pure, dry coal basis.

In these experiments we used a cast-iron bomb, heated electrically or in a muffle furnace. This bomb, with absorbing apparatus and gas holder, was devised by the writer about eight years ago, and has been much used in the laboratories of the U. S. Government, and in our laboratories, for determining the nature and amount of products from various coals under varying conditions.

	Wood.	Brown Lignite.	Black Lignite.	Illinois Coal.	Kanawha Gas.	Smokeless.	Anthracite.
Analyses (per cent):							
H_2O and volatile	75	70.5	65.6	42.0	29.0	20.0	7.9
Fixed carbon	25	29.5	35.0	58.0	71.0	80.0	92.1
Temp. decomposition (deg. Cent.)	150	230	260	300	330	330	340?
Temp. range of expts. (deg. Cent.)	150–188	230–320	260–340	300–330	300–360	330–400	230–475
Litres gas evolved from 500 gms.	43.5	10.8	14.0	11.5	14.0	9.3	4.6
Cubic feet gas per ton	3,080	750	1,000	815	1,000	659	326
Gas analysis (p. c.):							
CO_2	58.6	55.6	49.3	24.1	7.3	6.5	10.3
C_6H_6	0.5	0.6	0.9	2.8	0.5	2.6	1.3
C_2H_4	0.6	1.0	0.8	2.2	1.4	2.3	0.4
CO	35.0	24.7	19.5	10.6	6.0	4.1	2.6
CH_4	1.3	11.4	19.5	43.3	57.4	53.5	70.6
H_2	1.0	0.3	0.0	3.4	14.6	9.7	0.0
N_2	3.0	6.4	10.0	13.6	12.8	21.3	14.8
Per cent by weight volatilized	51.9	26.8	31.0	23.7	12.2	10.0	0.7
Analysis of residue:							
Volatile	56.0	39.0	30.8	23.3	18.7	13.9	7.1
Fixed carbon	44.0	61.0	69.2	76.7	81.3	86.1	92.9

The residue from the first carbonizing test on the brown lignite was again heated from 450 to 500 deg. Cent., producing 3,500 cubic feet per ton of gas of analysis as shown under heading "A."

This second residue, heated again to 920 deg. Cent., gave 7,000 cubic feet of gas of analysis under heading "B."

	"A" Per cent.	"B" Per cent.
CO_2	27.2	7.0
C_6H_6	5.5	1.2
C_2H_4	3.2	1.1
O_2	.7	.5
CO	9.2	22.5
CH_4	38.4	18.3
H_2	12.0	41.8
N_2	3.8	7.5

Evidently from these tests decomposition gradually brought about by heat tends to drive off at first the high oxygen content, and each coal type is converted into a type similar to, though not exactly like, the succeeding higher grade fuel.

In the case of wood, the gas first evolved contains about 97 per cent of CO_2 and CO. Similarly the lignites and Illinois coals first give off a high percentage of oxygenated compounds, and in this way necessarily the residues contain less oxygen and are of higher calorific value.

Under high pressures doubtless a sharper fractional decomposition would result, and the residues even more closely resemble the natural fuels.

At any rate, such slow, artificial carbonization is strikingly suggestive of nature's process. These residues show decided resemblances to the natural product. That they are not identical, both physically and chemically, may be due to the high pressure used in nature which we have made no effort to duplicate.[5]

NATURAL GAS A BY-PRODUCT OF COAL.

But if natural gas, chiefly methane and hydrogen, is a by-product of nature's carbonizing processes, we must explain the disappearance of the large amount of carbon dioxide and carbon monoxide which was originally present in such decomposition gases. May we not assume that the CO_2 has been absorbed from the gas by the alkaline earth waters produced by weathering rocks, and that the carbon monoxide has been absorbed and oxidized by metallic oxides?[6] Gas thus obtained from carbonizing lignite, for example, by removal of CO_2 and CO would be practically identical with natural gas. Thus, calculating out the CO_2 and CO from the gas obtained in heating lignites at low temperatures, we have left a gas containing principally methane, i. e., a typical natural gas.

CLASSIFICATION OF COALS.

Now that we understand the nature of coals as different residues in the progressive decomposition of wood into graphite, we are in a position to classify them. Rejecting accidental impurities, such as ash and sulphur, and using the pure coal basis, coals may be classified in several ways. Five important differences are suggested on the following chart as bases of classification; for example, moisture, volatile, oxygen content, calorific value, and finally, initial decomposition temperature. Specific gravity, total carbon, oxygen content, and other characteristics might also be given, all of which indicate the same progressive change in characteristics.

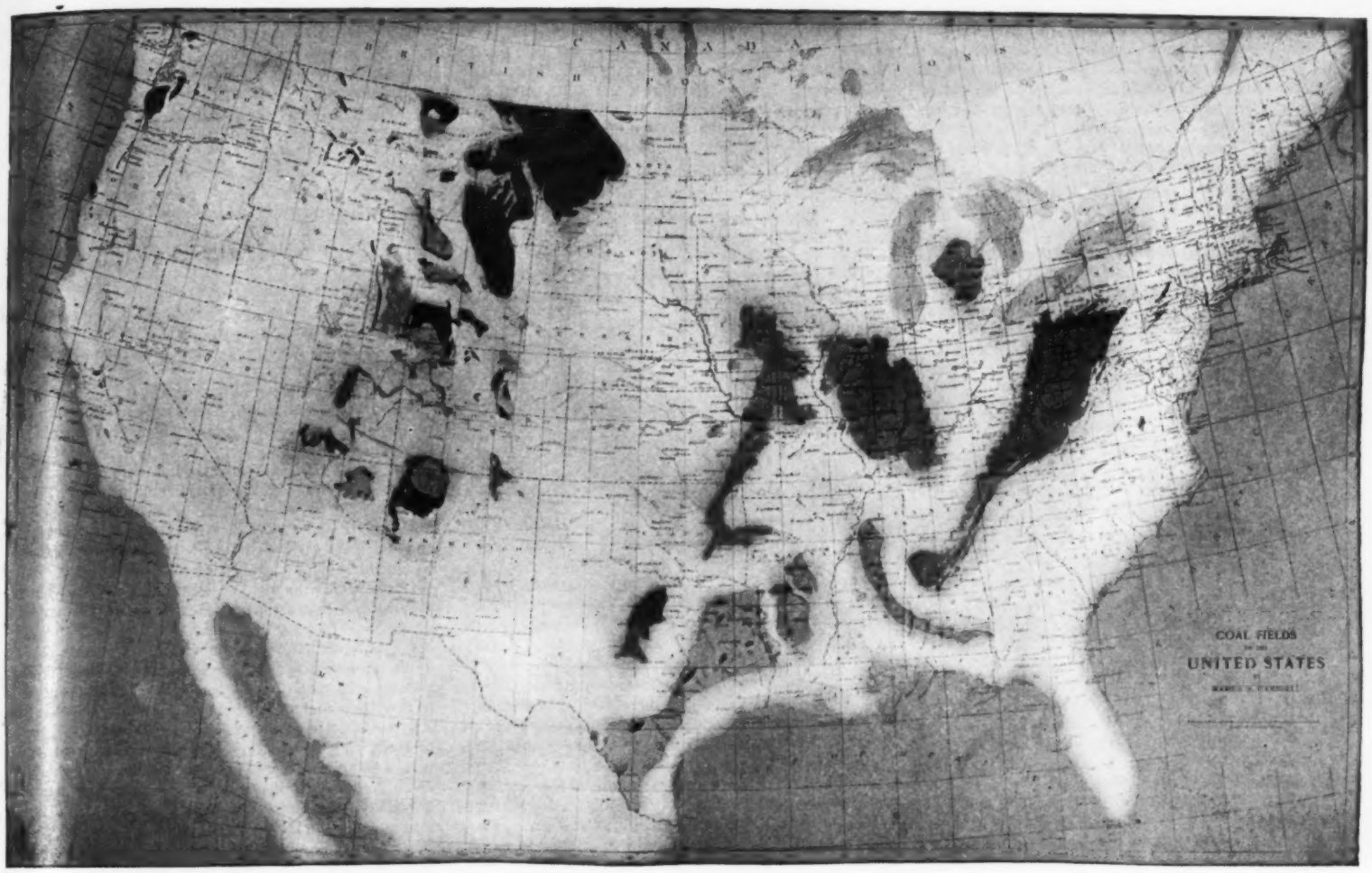
* Presented at the meeting of the Section of Physics and Chemistry of the Franklin Institute, and published in its *Journal*.

[3] Mabery's study of "Mahone Petroleum, its Recent Origin and the Origin of Petroleum in General," has just come to my attention. The evidence given leaves little doubt that petroleum is one of nature's by-products of coal.—*J. I. and Eng. Chem.*, February 14th, p. 101.

[4] Pictet & Bouvier, Ber., 1913, p. 3342.

[5] Results obtained by Ralston, U. S. Bureau of Mines, when plotting the composition of coals by the ingenious triangle method, indicate that the curve of decomposition bends strongly as semi-anthracite is approached, corresponding to the bend in our curve for calorific value of volatile matter.

[6] It is well known that CO in the presence of hydrogen can be oxidized to CO_2 without attacking the hydrogen by passing over metallic oxides. This selective oxidation is possible with ferric oxide and with copper oxide. Temperatures as low as 250 deg. Cent. are sufficient.



Distribution of coal in the United States.

BETTER STANDARDIZED ANALYTICAL METHODS REQUIRED FOR VOLATILE MATTER AND MOISTURE.

Unfortunately it is necessary to call attention to the lack of uniformity in methods of determining moisture and volatile matter in coals, since much of the data given in the tables presented depends in particular upon consistent results in the determination of these figures.

An atmosphere standing over a calcium chloride solution containing 35.5 per cent anhydrous chloride will show a test at any ordinary temperature of 50 per cent relative humidity. Likewise atmosphere in equilibrium with calcium chloride solutions will have the following relative humidities:

Calcium chloride. Per cent.	Humidity. Per cent.
26	60
12	40
20	50
30.5	30
35.5	70
41	90
45	80

A coal in such an atmosphere will, like any other hygroscopic material, take up and hold a definite amount of moisture according to its position among the types of fuels shown on chart VI, bottom of this page.

Volatile tests can be made with much satisfaction by use of the Meker burner, but perhaps for strict comparison standardized conditions in a muffle furnace are better.

Evidently as we progress in the series, volatile matter, oxygen and moisture go down, while calorific values and temperatures of decomposition go up. As decomposition progresses the specific gravity also goes up.

I am not aware that the decomposition temperatures of coal types have ever before been studied, but since, as we have assumed, coals are residues representing the different steps in nature's carbonizing process under progressively severer conditions, it is only natural that they should have different, and, as we go up the scale, increasing temperatures at which they begin (again) to decompose. That these decomposition temperatures are progressively higher is a further strong indication that coals really are just such residues as has been assumed.

Low grade coals contain much moisture. They are, in fact, hygroscopic, and will, like other hygroscopic materials, when dried take up again moisture from moist air in proportion to its relative humidity.

As has sometimes been assumed, high volatile coals are not geologically new coals, nor are smokeless coals of an older geological formation, as is evident from the wide variations in volatile found in coals from the same geological seam. For example, the Pocahontas coals vary in volatile from say 16 per cent in the true Pocahontas district, to above 30 per cent in the equivalent geological New River district north of Meadow River, W. Va.

Though coals were formed from vegetation at the beginning of the carboniferous era, in the presence of more carbon dioxide in the air than later coals, this does not seem to have been the cause of any real difference in their character.

The classification, however, of coals on the basis of temperature required to decompose, is rational, as is strikingly shown from a study of coal deposits everywhere. In Washington State there are coals of all types from lignite to graphite, and, under different conditions, all types may be found in what appears to be the same geological horizon. When the seam is horizontal the coal is lignite; when somewhat disturbed and oblique the coal is generally a gas or smokeless coking coal; when folded it becomes anthracite, and finally, when pierced by igneous rock, we have graphite.

COKABILITY.

In commercial work for our purposes coking coals have also to be classified as to cokability. In the following

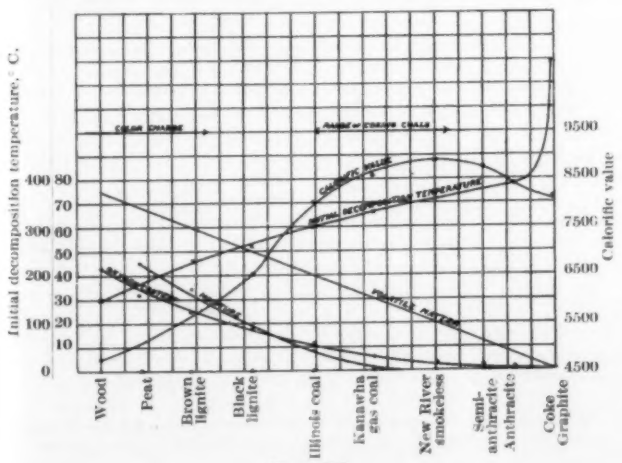


Chart VI.

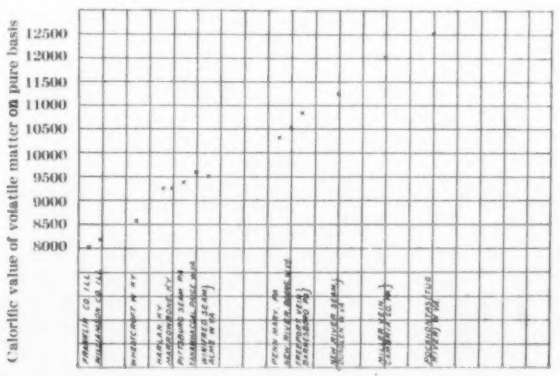


Chart VII.—Table showing calorific value of volatile matter for typical coal fields of the United States.

manner, which really is based upon oxygen content, though not requiring the tedious ultimate analysis necessary to give oxygen content, we have classified coals as to cokability, using as a basis the calorific value of the volatile matter contained. This, for coals of the same percentage volatile content, fairly represents cokability in actual coke-oven practice.

On chart VI (page 133) the range of possible coking coals was indicated. Now, by deducting the calorific value due to fixed carbon (calculated) from the total calorific value, and dividing by the amount of volatile matter, all on the pure basis, we get a series of coals of increasing cementing or coking tendencies.

As shown on Chart VII, this variation in calorific value of the volatile matter has been found to represent results in actual coking practice.

As the calorific value of the volatile matter increases the cokability increases up to the point where the actual amount of volatile matter becomes insufficient to cement and hold the mass together. For example, semi-anthracite coals and anthracite, as to cokability, are beyond the limiting factor of insufficient cementing volatile material.

Cannel coal is unusual in that the calorific value of its volatile matter is higher than for any other coal with volatile so high. By the Ralston method of classifying and plotting it falls well above the usual curve.

Coals also differ as to the amount of materials contained capable of solution in caustic, pyridine, benzene and other solvents, and may be classified accordingly. So the residues from artificial carbonization at low temperatures give different amounts of matter soluble in the various solvents.

Finally, on exposure to moist atmosphere, coals decay. They become oxidized and go back in the series. For example, by taking up oxygen and water a good coking coal takes on the character of a poor sub-bituminous coal or of the qualities of the non-coking lignite.

Coals, and their by-products, are therefore not such mysterious materials. They are merely intermediate bodies resulting from the decomposition of ancient vegetation, just as a multitude of substances may be obtained by violent or gradual decomposition with heat of any simple organic compound.

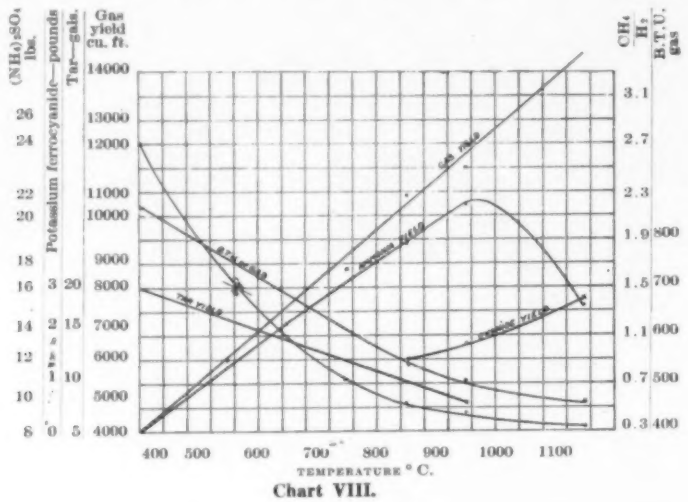


Chart VIII.

COMMERCIAL MANUFACTURE OF COKE AND BY-PRODUCTS.

The conversion of bituminous coking coal to its anthracite-graphite equivalent, coke, has become of extreme commercial importance, and particularly when this is done with the recovery of the by-products. A ton of average coking coal will produce in the modern by-product oven:

1,500 pounds coke.

18 to 26 pounds sulphate of ammonia.

6 to 10 gallons tar.

1½ to 2½ gallons mixed light oils (benzole, toluole, xylole).

1½ pounds ferrocyanid.

By further elaboration, from these light oils and tar practically all the compounds mentioned in Beilstein may be produced.

On Chart VIII is indicated the influence of temperature upon the yields and character of the by-products obtained from an average coking coal. The temperatures given represent the hottest part of the retort at the beginning and end of the carbonizing period. The average temperature would be considerably lower.

On this chart the yield of light oil is not given, but our experiments indicate a mixmum yield of this material at about 500 to 550 deg. Cent.

VIRGIN COAL FIELDS IN THE UNITED STATES.

With this article are given some pictures selected from photographs taken by the writer to illustrate conditions in the virgin coal fields of the United States. These good Americans, with conditions of living which the discoveries of Koch and Pasteur have not yet reached, represent a backward glimpse into the frontier life of our own colonists' forefathers; this log cabin, timber clearing, horseback, spinning-wheel life, with its quaint Shakespearean dialect, is rapidly passing. A permanent record of some of these things is, therefore, of scientific value.

The "Britannia" Airship

By Major Bannerman-Phillips

A FUND is being raised in Great Britain by public subscription to build and present to the government, if it is found suitable by the naval authorities, a new type of dirigible to be called the "Britannia" airship. It is the invention of Mr. J. Wulffing, an ingenious nautical engineer. The method which will be employed in maneuvering is that of Mr. A. de Bajza.

The chief point in the construction is the method of building up the aerostat, which combines the advantages of the rigid type as regards protection of gas containers, maintenance of shape (even when gas is lost) and facility of steering with those of the non-rigid type in that it can lie flat when deflated, and this is the chief factor in insuring a far greater net lifting power than is possible with any other known type of airship.

The hull is built up of longitudinal steel tubes *a*, suitably braced together, having their ends fixed to metal nose-pieces at either end. A central steel cable runs from bow to stern and braces the whole structure, making it perfectly rigid. The structure, or framework, is suitably covered with fabric. The inside may be divided into partitions, thus preventing complete loss of gas if punctured.

The base of the aerostat is left flexible by the omission of two or more steel tubes (in this case 3), whose place is taken by elastic strands. When the gas expands or contracts, owing to atmospheric changes, the increase or decrease in volume is taken up by the loose belly thus formed; this prevents loss of gas when expansion takes place. This belly is contained in a covering by which the car is suspended from the aerostat.

This covering forms an air channel which has an opening at front and rear *k*, through which the front propeller drives a current of air, thus removing any loose gas which may otherwise have collected. The necessity for this, or some similar arrangement, was pointed out in the SCIENTIFIC AMERICAN of November 22nd, 1913.

The engines are six in number, three of which are mounted at the front, and three at the back. In front is one central motor *b*, while just behind it are two others *c*, carried on outriggers which extend upward at the sides of the aerostat. A similar arrangement, in reversed order, is adopted at the rear.

The motors are so placed that the center of propulsion coincides with the center of resistance as nearly as possible.

As the propellers are directly coupled to the motors there is no loss of energy due to transmission. This means more propulsive power than stationary engines, giving the same nominal equivalent in horse-power; in fact, an increase of approximately 20 per cent. The propellers and car are so arranged that landing can be effected on either land or water without fear of damage.

The front and rear motors are so constructed and so fixed as to be capable of being tilted up and down and swiveled right and left to aid in steering; this is especially important when ascending from or alighting in a limited space, as it allows the airship to be turned about in its own length.

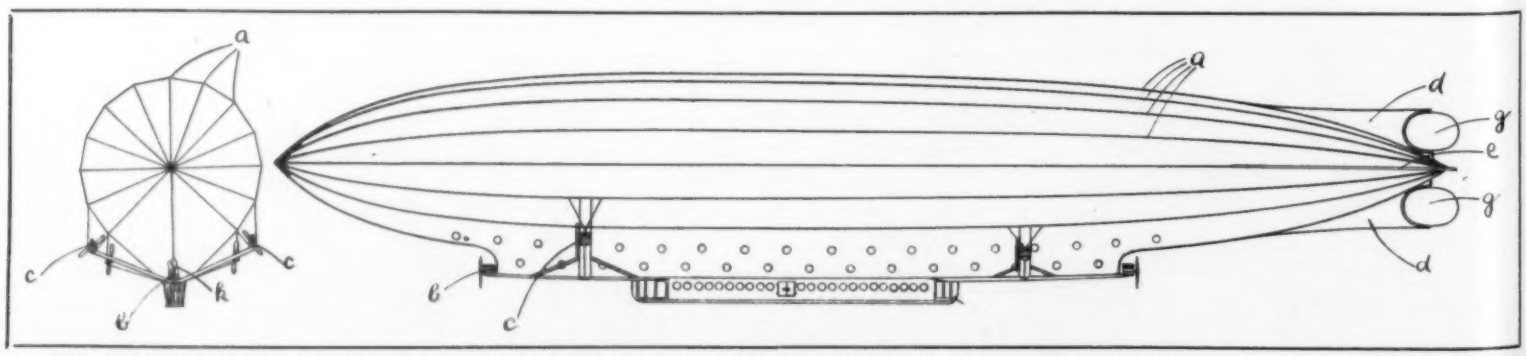
At the rear of the aerostat are two vertical stability planes *d*, and at the rear of these again are two rudders *g* for horizontal steering, which are pivoted one third of their distance from the front. This arrangement insures ease and efficiency of control. There are also two horizontal stability planes *e*, which have elevating planes pivoted in the same manner as the rudders.

The following are the main dimensions and particulars as regard the airship:

Length	340 feet
Maximum diameter	52 feet 4 inches
Average diameter	40 feet
Capacity	350,000 cubic feet
Gross lifting power	29,325 pounds
Total weight, with car and engine	16,670 pounds

As the total lifting power is 29,325 pounds and the total weight is 16,670 pounds, the net lifting power is 12,655 pounds, or 43 per cent. This compares very favorably with the Zeppelins, which have a net lifting power of only 28 per cent; thus, Mr. Wulffing's airship has 53 per cent more net lifting power than the Zeppelins, but if of the same size, the net lifting power would exceed that of the Zeppelins by about 85 per cent.

This high efficiency as regards net lifting power is obviously an enormous advantage, since it means that more actual weight can be carried in the shape of fuel, cargo, ballast, passengers, wireless telegraphy apparatus, or explosives. In time of war, when the airship might have to remain aloft for long periods, it would enable the vessel to carry a crew sufficiently numerous to work in reliefs, or to transport ammunition rapidly when urgently wanted, say in a beleaguered fortress, or to renew the exhausted supplies



a are longitudinal steel tubes; three of these tubes are omitted at the bottom to provide room for an elastic belly which swells out as the gas expands. Loose gas is driven out of the covering in which the belly hangs by a propeller.

The "Britannia" airship.

of a detached force over the heads of an intervening enemy.

The Zeppelin vessels are the most successful rigid dirigibles up to the present. Taking them as a standard, Mr. Wulfling's airship compares very favorably in the following points:

Although it is absolutely rigid, the construction is so light that if it were built of the same capacity as the Zeppelins, with double the size of car for passengers, and larger fuel containers, it would still have 80 per cent to 90 per cent more net lifting power than the latter.

The higher efficiency permits of an increase in speed up to 55 or 65 miles per hour.

The higher net lifting power enables the dirigible to take in more fuel for a longer radius of action in time of war.

On the "Britannia" airship quick-firing guns, with ample supply of ammunition, a larger crew, wireless apparatus, etc., can be carried.

For civilian use, a good income could be earned by passenger carrying and displaying advertisements, illuminated at night.

If gas were lost or a high altitude desired, 25 per cent of the total weight of the ship could be sacrificed in ballast or fuel, owing to the high net lifting power.

A sacrifice of 25 per cent would give an additional altitude of about 7,000 feet, and a further altitude up to 12,000 feet could easily be obtained by tilting the nose of the ship up a few degrees from the horizontal and driving at full speed; if the bow and stern motors themselves were tilted upward a few degrees, this of itself would give additional lift.

Mr. Wulfling's airship, of the above-mentioned displacement, would have a speed of 55 to 65 miles per hour, and a radius of action of 800 miles, or it could make a single voyage of 1,600 miles without taking in fresh supplies of fuel.

Apart from the above advantages, the one of cost is very considerable.

The cost of an airship, equal in size to the Zeppelin, would be $75,000, as compared with $165,000 of the latter. The cost of the "Britannia" of smaller size, with greater efficiency than the Zeppelin, will not exceed $50,000.

Aerial Reconnaissance During Sieges*

Its Important Influence on Artillery Attack and Defense

By E. Kabisch

Not many years ago the search for masked batteries was confined to howitzers and mortars. Field guns were always placed on heights, from which the eye of the gunner could follow the quick movements of the infantry and cavalry, and discover the approaching artillery of the enemy before it had come within firing range. It was supposed that the introduction of the gun shield would increase the effectiveness of this open method of warfare.

The experience of the Russo-Japanese war brought forward advocates for the masking of field pieces, but this suggestion was violently opposed at first. I remember that a division commander who had risen from the field artillery said to me, in discussing the maneuvers in 1906: "I should not like to show my division the spectacle of artillery hiding behind hills." But the advocates of concealment prevailed and soon it became necessary to remind the artillery that the exigencies of battle might eventually require it to break cover and come out into full view of the enemy.

The foot artillery still more eagerly adopted the employment of concealed positions, and greatly developed their possibilities by improving methods of aiming and observation. The destructive action of modern heavy artillery is so great that a battery once discovered by the enemy appears doomed to speedy annihilation. These arguments apply still more forcibly to sieges, in which victory, for either combatant, depends mainly upon his ability to unmask the enemy's batteries and conceal his own. In this contest the advantage that the besieged can derive from thorough exploration of the ground in time of peace, is partly counterbalanced by the wider expansion of the besieging forces and their ability to utilize every possibility of the ground.

Aerial reconnaissance has long been employed both in sieges and in the field. Until recently reliance was placed mainly on captive balloons, although the use of free balloons, to a limited extent, in sieges, was also advocated. No extravagant hopes were entertained in regard to the captive balloon. It presents so excellent a mark for artillery fire that it cannot be used within the range of shrapnel, and its ability to discover small objects is slight, especially in the foggy climate of Europe. The free balloon, sent up by the besiegers to float over the invested fortress and to photograph its details, must also float very high, in order to escape destruction, and the objects photographed are largely determined by chance. The free balloon is of still less value to the besieged, because it is impossible to bring it and its photographs back to the fortress. In open campaigns no attempt has been made to use free balloons for reconnaissance.

The development of the airship, and especially of the aeroplane, is rapidly bringing about a complete revolution in aerial reconnaissance. It can be a question of only a few years before the progress of aviation will make it possible to discover every battery in the field. This development leads inevitably to the construction of aerial battleships, fitted to attack and destroy each other.

In the field both combatants will be able to employ aerial fleets, but these will be exposed to attack from land batteries, as well as from each other. This fact and the shortness of the time available for reconnaissance will enable many batteries to escape possible detection.

In sieges the conditions are very different. It is *a priori* impossible for the defenders to contest the command of the air for any long period. In the first place, they will be poorly equipped with aeroplanes, which will be assigned chiefly to the field corps. The besieged fortress will be fortunate if it happens to possess a few serviceable machines and a few skilled aviators. This little aerial squadron will soon be destroyed by the vastly greater fleet of the enemy, and it will be impossible to replace it.

The superior claim of the field corps will prevent the sending of reinforcements to the aerial squadron of the fortress, and even if they should be sent, the incoming vessels would be in danger of being shot down by both friends and foes, as it is almost impossible to distinguish between aeroplanes in flight.

The fortress can train its guns upon the aerial scout of the enemy and seriously hamper him in his work of aerial reconnaissance, but it is obvious that the development of aviation has given the besieger a great advantage. Telephotographic views, taken from his aeroplanes, will reveal defending batteries lurking behind hills, and if expert artillery officers are placed on the areoplanes as observers, the prospect of speedy destruction of the unmasked batteries become at once very favorable.

For averting this discovery and destruction there are only two means—the gun shield and the mask of trees. The gun shield cannot escape the eye and the camera of the aviator, but its destruction requires such accuracy of fire that the mere knowledge of its location, even if laid down correctly on a plan, by no means decides its fate. Its systematic destruction requires either accurate lateral observation or a great expenditure of very costly ammunition.

This most efficient protective device, however, is itself so costly that it can be employed only to a very limited extent. Moreover, the gun so protected is fixed to one spot. It cannot be moved from a part not attacked to a place where it is most needed, and it cannot be used by a besieging force.

Masks of trees, if properly arranged, present very serious obstacles to aerial reconnaissance. A few narrow lines of trees will not suffice; numerous irregular groups are necessary. For this reason large orchards, distributed among meadows and cornfields, are very effective. Where this method of cultivation is customary, as it is in Alsace-Lorraine and Baden, the free distribution of young trees and the offer of prizes for their cultivation would induce farmers to plant orchards on their own land. In this way the cost of acquiring land for this purpose would be saved to the military administration—provided that it was supported willingly, skilfully, and discreetly by the civil authorities. This method is a slow one, as years would be required to produce sufficient protection for artillery. For this reason this inevitable development should be begun without delay.

The adoption of these protective measures is only part of the defender's task. He will be compelled, more than ever before, to seize in advance all commanding heights near the fortress, in order to observe the enemy without the aid of aeroplanes, and to assure free scope and long range for infantry fire. For if the defending batteries fail to escape discovery by the besieger's aerial scouts, and prove unable to sustain the combat with invisible enemies, their only chance of success lies in retreating so far that the enemy's siege guns cannot reach them without breaking cover and coming into view of the defenders.

At first sight this retreat appears to involve a sacrifice of the infantry, whose positions are now left without artillery protection and exposed to the fire of the heavy siege guns of the enemy. This exposure, however, is unimportant if the infantry positions are fortified so strongly that they can defy the attack of the distant siege guns. Only the attacking *infantry* can force the defenders to show themselves on the breastworks, and the attacking infantry cannot do this without exposing itself to the fire of the retracted artillery of the defenders.

Here we come to a tactical method that is often employed in the field—the so-called artillery cartel. The artillery of each side ignores that of the other and directs its fire on the infantry, which, as usual, pays the toll of blood. Yet the artillery of the besiegers cannot disregard its own infantry's cry for help, and is obliged to advance far enough to renew the attack upon the *retracted* defending batteries. This is the commencement of the decisive conflict, in which a very important part is played by the possibilities of cover afforded by the ground within a mile of the infantry positions of the defense. If the defending artillery can hold its own in this part of the fight, in which its chances are far better than in the initial engagement at long range, the attack of the besieger's infantry may be stopped.

This result cannot be accomplished unless the positions of the defending infantry are strongly fortified. If they cannot withstand the enemy's artillery fire they will be captured easily, without even compelling the attacking infantry to make a gradual and perilous approach.

The required protection can be given only by permanent fortifications, but these need not be storm-proof at every point. The character of the front and the foreground should be taken into consideration. Open ground, affording a view of the enemy's action, is in itself a great protection (even at night, with the employment of searchlights) and gives the retracted defending batteries free scope. Hence infantry cover, so situated, need not be absolutely storm-proof. But if the foreground affords the attacking infantry cover at short range, the positions of the defending infantry must be very strongly fortified in order to escape being taken by assault. The fortifications, therefore, should be adapted to local conditions, not constructed according to a uniform type, without regard to expense. They should always, however, assure ample protection to the men. Otherwise, in view of the limitation of the powers of the defending artillery by the development of aerial reconnaissance, the fortress will soon fall an easy prey to an energetic, systematic, and well equipped besieging force.

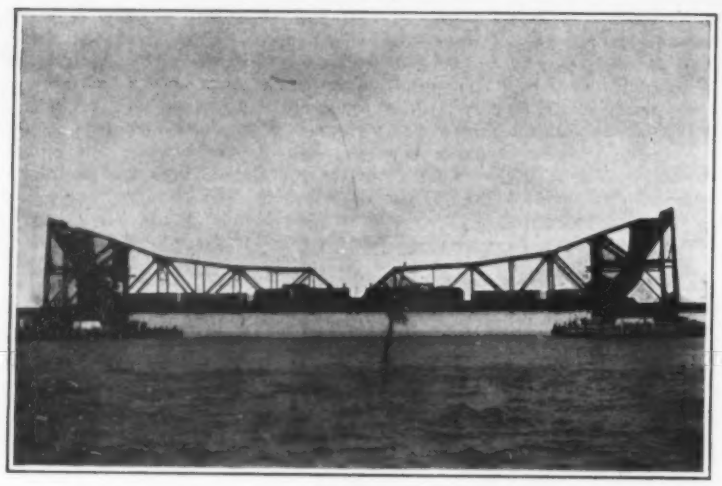
CONCLUSIONS.

The development of aviation has given the besieger an important advantage. In addition to the possibility of injuring the fortress by aerial attack (a point which is here purposely passed over), the artillery combat is influenced greatly to the disadvantage of the defense. The employment of gun shields cannot be much increased, hence the guns must be masked by trees, or otherwise, as well as possible. Furthermore, it must be understood that the defending artillery will soon be forced to retreat before the overwhelming fire of the hidden siege guns of the enemy, and that the decisive action will be the infantry attack upon the positions of the defending infantry.

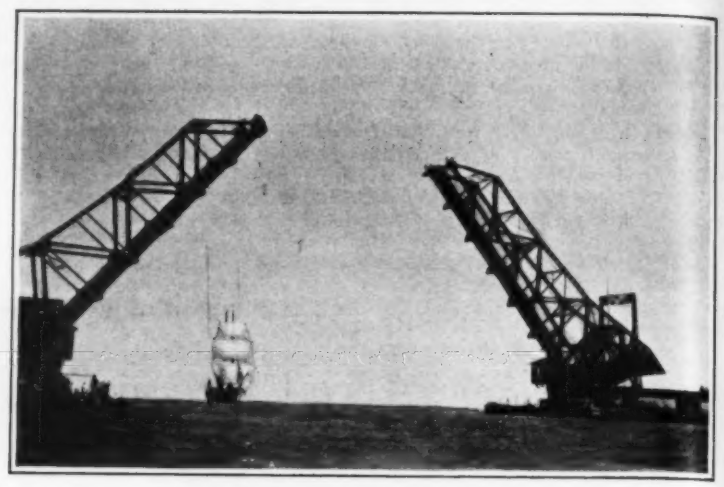
If these positions are insufficiently fortified they will be quickly destroyed by the distant fire of the besieging artillery. If, on the contrary, they are bomb-proof, the attacking artillery will be forced to advance and endeavor to destroy the retracted batteries of the defense. In this second duel the unconcealed and unprotected attacking artillery will be in serious danger of annihilation.

It may be objected that I have overlooked the possibility of the employment of aerial scouts by the defense for discovering the enemy's preparations for attack. I doubt whether the defense would long remain in possession of an aerial fleet, which would be the first object of the enemy's attack.

* Translated from *Militär-Wochenblatt*.



The roller lift bridge with test load of locomotives and cars.



The bridge open for a typical sailing vessel.

Linking India and Ceylon by Railway

Difficulties of Bridge Construction With Native Labor

By F. C. Coleman

A DIRECT connection between the railways of India and Ceylon has lately been opened. This scheme comprised the extension of the South Indian Railway from Mandapam, on the mainland of India, to Danushkodi, on the island of Rameswaram; an extension from Madawachi, on the main line of the Ceylon Government Railways, to Talliemanaar, on the island of Manaar; and the construction of two piers and customs, postal and railway quarters at each of the railway termini, for the service of the ferry steamers provided between them. In addition, a quarantine camp has been constructed near Mandapam for the detention of Indian coolie labor *en route* for Ceylon.

The most interesting work was the bridge construction across Palk Straits along the reef extending from the mainland of India to the island of Rameswaram. The structure, commencing from Ramen Point on a narrow sandy promontory called Toni Torai, about 2 miles from Mandapam, consists of 112 plate girder spans of 40 feet, one of 43 feet, a Scherzer rolling lift bridge of 289 feet, one plate girder span of 44 feet and 31 spans of 40 feet, extending to Pamban. At the Scherzer span, Pamban Pass, an artificial channel made some fifty years ago, provides for coastwise navigation. This is the only navigable channel between India and Ceylon, and has a depth of about 14 feet. The substructure for the Scherzer bridge consists of two 9-foot and two 12-foot cylindrical piers at each side of the channel, extending down about 45 feet below mean sea level into a stratum of stiff yellow clay. The cylinders on the Pamban side were sunk with an air-lock, but those on the Toni Torai side were sunk by dredge and divers. To facilitate the sinking of these cylinders two artificial islands were made of coral boulders and concrete in sacks inclosed within a timber caisson and covered with clay and sand.

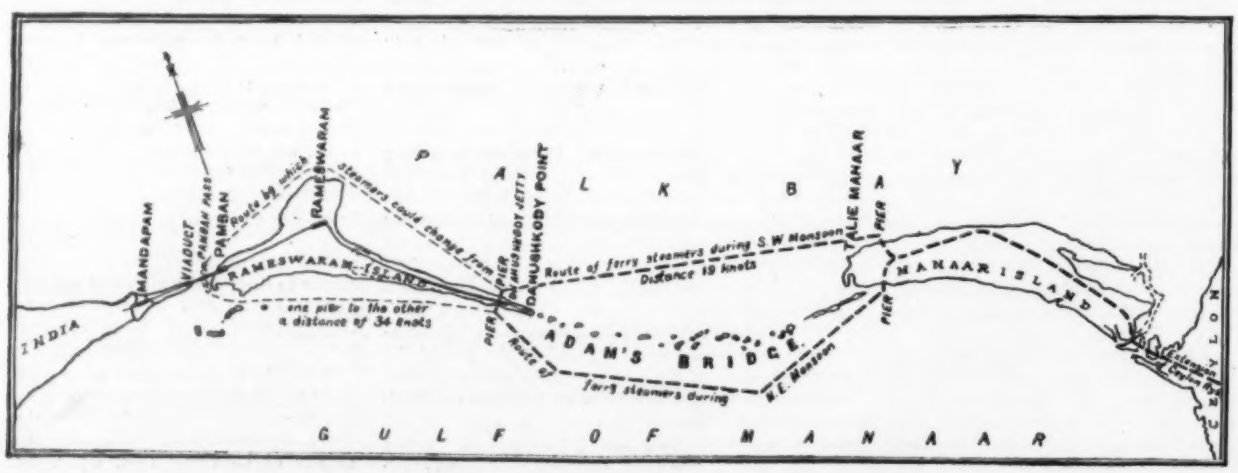
From an engineering standpoint the erection of the Scherzer bridge is of interest because native Indian labor was used solely, and because, to prevent interference with navigation, the leaves were erected in a position inclined about 60 degrees to the horizontal, despite the high winds and strong currents prevailing.

The bridge is of the double-leaf, through type, for single track of 3 feet 3⅜-inch gage, with a span of 225 feet between bearings, and a width of 20 feet between center lines of trusses. The erectors were Moplahs, who are natives of the Malabar coast on the western side of India. They were employed by two contractors, each of whom had been awarded the contract for the erection of one leaf and had previously erected the 40-foot girder span. The rivalry between the two crews, although not always friendly, did much toward expediting the completion of the bridge. The Moplahs did not have much previous experience of bridge erection, but were strong and active and skillful at rigging work. All other labor was employed directly by the South Indian Railway Company, and was composed mainly of Anglo Indians (Eurasians) and Tamils as foremen, engine men, mechanics, rivet inspectors, painters, and boatmen, in addition to the coolies of both sexes.

Hindu Temple at Rameswaram Island.

The average hours of work were about ten per day, and work was carried on continuously, on Sundays as well. Occasionally a Mohammedan feast day would stop the work. During the Mohammedan fasting period, which continued for thirty days from August 4th, work stopped at about 4 o'clock every afternoon. Then the Moplahs abstained rigidly from eating, drinking, smoking and chewing from sunrise to sunset, notwithstanding the climatic conditions, and even tried to abstain from swallowing.

Erection work commenced on July 20th with the drilling of holes in the anchorages for the anchorage column splices. The 12-ton track girders were then moved and hoisted into place by means of tackle and hand winches and a gantry or framework of teak poles lashed together, on each island which had been left standing after being used on the substructure work. Because of the small space on the islands, only a few pieces could be brought at a time from the storeyard at Toni Torai. The materials for each half of both leaves had been painted a distinctive color in addition to the erection marks, so that the most illiterate of the workmen could distinguish them. Riveting was performed by pneumatic tools, as well as the drilling and reaming necessary. The riveting done was a source of annoyance at first, due to the inexperience of the workmen, but as the work progressed the riveting improved, and



Map showing the new railroad connection between India and Ceylon.

they were able to drive the rivets at a rate of 250 a day per squad. When the fixed portions of the bridge had been erected and the segmental girders and some of the subsequent pieces placed and blocked up in their proper positions, the gantry poles used for erecting were removed and the counterweight boxes assembled. Riveting followed closely on erecting, and after completion of the counterweight boxes, forms of ⅝-inch teak wood for the adjustment pockets were put into place in the boxes by Indian carpenters from the construction workshop at Toni Toral. Though these carpenters, like the other Indian workmen, used tools and methods that do not wholly conform with English and American ideas, and had little knowledge of plans, their work was good. In one respect they have the advantage of being adepts in supplementing their handicraft with foot-craft. Stacks or cribs of old railway ties were placed to support the counterweight wings during the unbalanced condition of the leaves, and runways were built for placing the counterweight concrete. A concrete mixer of half a cubic yard capacity, mounted on a pontoon scow, moored at each island was used. As the batches of concrete were mixed they were dumped upon the deck of the scow and shoveled into galvanized iron dishes, about 12 inches in diameter and 5 inches deep. The concrete was carried up the runways in these dishes by the coolies, comprising young boys and women of all ages, and passed along to be deposited in the counterweight. In this way as much as 2 cubic yards per hour could be placed. While the concreting was going on the erection and riveting were also progressing. Two panel lengths of top chords for each truss, the adjacent web members and the machinery floor and bracing for each leaf were in place, when an erection derrick was assembled to rest on the top chords of the second panel. By means of these erection derricks the web members, chords, floor, and bracing members were hoisted up and bolted in place in logical sequence.

The first train across the bridge was run through on December 14th. In connection with this the Hindu belief in "inauspicious occasions" was brought up. According to Hindu religious chronology one of these occasions commenced at 4 P. M. on the 14th, during which any new undertaking would result in misfortune and disaster. Because of that, the work of track laying was continued throughout the previous night, so the first train was run across the bridge at about 10 minutes to 4, with no cause for misgivings on the part of the interested Hindu spectators.

As regular passenger traffic across the bridge has now commenced and a through service from the main line of the South Indian Railway to Danushkodi is inaugurated, the ferry service between Mandapam and Pamban, which previously served the immense pilgrim traffic—at times amounting to more than 30,000 passengers per day—has been discontinued.

Operator's house on the roller lift bridge.

The Thyroid and Thymus in Relation to Development

In speaking of growth or development, those who do not give close attention to the problems involved in this phenomenon usually emphasize primarily the increase in size or weight which familiarly characterize it. The growth of the organism as a whole, particularly at an early period, is accompanied by another feature, that of differentiation. The changes in form and weight do not consist merely of additions to the tissue elements already laid down, but frequently also include those alterations whereby new types of structure are added to or evolved out of the primitive ones originally present.

The striking experiments of Dr. Gudernatsch[1], of the Department of Anatomy at Cornell University Medical College in New York, lend a peculiar emphasis to the fact that in development we may deal with two entirely separate factors, one of growth and one of differentiation. This was brought out by feeding to developing tadpoles certain mammalian glands with so-called internal secretion. The results, which have now been abundantly verified, leave no doubt that the thyroid gland contains something which, when the gland is given as food, calls forth a rapid differentiation in a developing vertebrate organism. This may be brought about at any stage of development before maturity is reached. The differentiation may therefore be highly precocious if the treatment is begun on extremely young animals. For example, tadpoles could actually be brought to the point of metamorphosis within eighteen days after hatching, while normally they would require ten or twelve weeks to reach such a stage. The results of this premature metamorphosis are perfect frogs of minute size—pygmy frogs. The thyroid influence is very decided and no tadpole given a thyroid diet escapes from it. Each individual, even if thousands be employed, as was the case in several experiments, will react almost immediately to the thyroid stimulus, so that certain changes in its structure may be observed twenty-four hours after a single feeding of thyroid.

If thyroid is given to these differentiating animals too rapidly, they usually die very soon after the appearance of their fore limbs and the reduction of their tails; but if they are fed carefully they may be kept alive for several weeks. They will not undergo any further changes except perhaps a continued reduction of their tails, nor will they ever feed again after this differentiation. During this period of excited differentiation, curiously enough, the animals fail to grow. Though the thyroid induces differentiation to a degree not common to other foods, there is no evidence that it possesses any power to prevent growth to the morphologic changes. The suppression of growth may merely be incidental, for rapid differentiation does not allow growth.

The thymus, on the other hand, has the power to stimulate growth, but lacks that of exciting differentiation. Tadpoles feeding on any food (except thyroid) reach a maximum size, and thereupon differentiation begins independently. Thymus-fed tadpoles experience a rapid growth, but fail to be brought to metamorphosis within the usual period. They are slow to develop their hind limbs, even though they grow in size beyond the normal. The thymus, therefore, possesses a quality that suppresses differentiation in a way not exemplified by any other food used.

Whether or not other glands share in any degree the accelerating or the depressing power so conspicuously shown by those already described at length, cannot at present be positively answered. The pronounced effects produced in developing organisms by the thyroid and thymus, respectively, at once suggest inquiries of the most diverse character regarding the possible rôle of these organs in the development of the human individual. For the moment we must remain content to record these exceptional experiences which show how specifically our food factors may be related to developmental processes.—*Journal of the American Medical Association.*

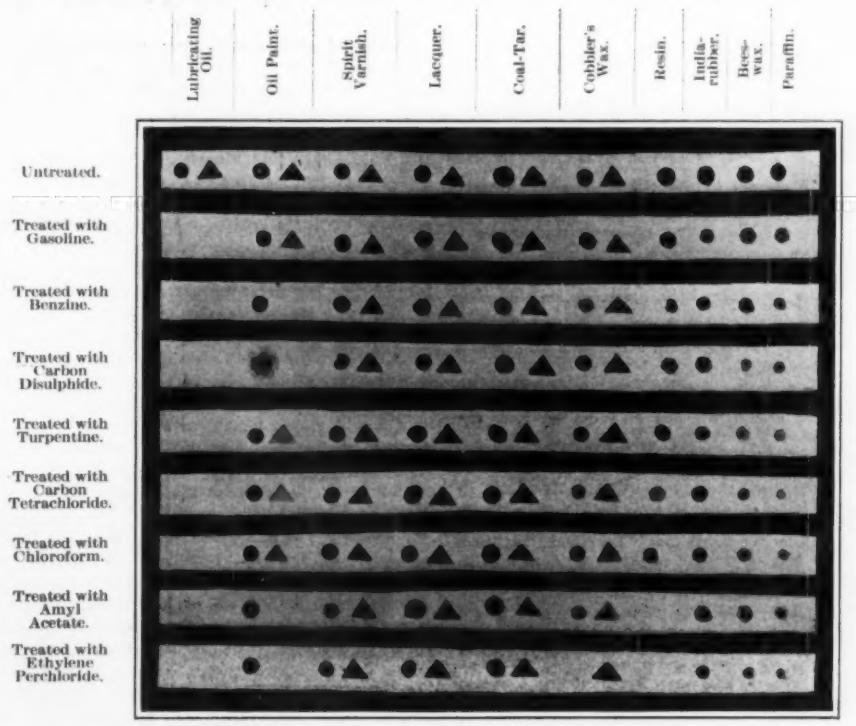
[1] Gudernatsch, J. F.: Feeding Experiments on Tadpoles I, Arch. f. Entwckingsmechn. d. Organ., 1912, xxxv, 457; II. A Further Contribution to the Knowledge of Organs with Internal Secretion, Am. Jour. Anat., 1914, xv. 431.

Preserving Eggs

When properly treated, preserved eggs are permitted by the officials responsible for food conditions in many States. One of the preserving methods that has given fairly good results is to carefully pack the eggs in a clean and well scalded keg, and cover them with a solution made up of one part commercial water glass (a solution of sodium silicate) in ten parts of water, well stirred. Eggs packed in this way and kept in a cool place will keep in good condition for six months or more. Sterile (infertile) eggs will keep much longer than fertile eggs. When preserved eggs are boiled they are liable to crack, but this can be prevented by pricking the blunt end of the egg with a pin before cooking.

Stains and Their Cures

The accompanying half-tone illustration requires little explanation. In order to find out the effect of any particular cleansing fluid on any particular kind of stain, look for the name of the liquid in the left hand column, and for the stain at the head of the table. A triangle refers to a fresh stain, a circle to an old one.—*Illustrated London News.*



By Courtesy of *La Nature.*

Greasy marks and methods of removing them.

The Principles and Theory of Mutation*

The Evolution of Species, Not a Slow Process, But Takes Place by Leaps

By Professor Hugo de Vries, of the Univerity of Amsterdam

UNITY of internal structure combined with a great diversity of external forms is the great principle of organic differentiation. Lamarck was the first to point this out and to explain it by his theory of common descent. But the science of his time did not afford a sufficient body of facts in proof of his conception, and he failed to convince his contemporaries.[1]

It has been the work of Darwin to accumulate a large number of facts and arguments, borrowed from the most diverse parts of the physical and biological sciences, and to combine the main results of the study of nature in general in order to find a conclusive proof of the idea of Lamarck. Common descent is now acknowledged as the natural cause of the unity of organization. Successive slow modifications have produced the great diversity of forms and the diverging lines of evolution which have gradually led to the highest degrees of differentiation.

But his broad views and comprehensive considerations did not suffice to afford the desired proof. Comparative anatomy and systematical studies, the knowledge of the laws of the geographical distribution of animals and plants and of their gradual development during the geological epochs, could only outline the broad features of the theory. Evidently its basis must be sought in the study of the process by which one species is produced from another. Which is the nature and which are the causes of this process? Which are the elementary changes which, by numerous repetitions and combinations, have produced the main evolutionary lines of the animal and vegetable kingdom?

In order to answer these questions, Darwin studied the experience of the breeders. The improvement of domestic animals was well known at his time; the cultivated races of flowers and vegetables, of cereals and sugar-beets, clearly and widely surpassed the same species in nature.

The method of breeders is based on the principles laid down about the middle of the last century (1840) by P. P. A. Lévêque de Vilmorin, the father of the celebrated founder of the culture of sugar-beets. He had observed the high degree of variability of cultivated plants and discovered that by means of a choice of the best samples and by their isolation highly improved varieties may be produced. His son has applied this principle to the sugar-beets, one of the most variable of all cultivated forms, and succeeded in increasing the amount of sugar from 7 to 14 per cent. This improvement soon became the basis of a large sugar industry in many countries of Europe. From that time isolation and selection have become the watchwords of a big new industry, which soon produced the most unexpected results in almost all parts of agricultural practice.

Darwin transplanted this principle of practice into pure science. He studied the variability of species in the wild condition and found it as widely spread and as rich in its features as in cultivated forms. He saw that very many species are distributed in nature in such a way as to constitute numbers of isolated colonies, sufficiently distant from one another to exclude the possibility of intercrossing. He discovered the great factor which replaces artificial selection in nature and called it by the name of natural selection. It is the unceasing struggle for existence and the victory of the most endowed individuals. In nature, every plant produces more seeds than can develop into new plants, owing to lack of space. Only those which are most fit for the surrounding conditions will survive, while the remainder are condemned to disappear. In this manner the struggle for life leads to a selection, which will be repeated in every generation, and a whole colony may gradually change by this means until at the end the characters are sufficiently different from the original ones to constitute a new variety or even an elementary species.

Natural selection in the struggle for life has now become the main principle of organic evolution. Since species obey in the wild condition the same laws as under cultivation, the principles of their improvement must be the same everywhere.

Darwin applied this principle to geological evolution also. Lyell had shown that the laws of nature have always been the same from the very beginning. Therefore natural selection must have been active from the first time of the existence of life on earth and have produced the main lines of differentiation, as well as the first traces of all those groups which are now recognized as families and genera. It is my conviction that the success of Darwin in this line of ideas has been as complete as possible. He succeeded in convincing his contemporaries of the essential analogy between artificial and natural selection.

But, on the other hand, it must be conceded that the practice of breeders was not as simple as it seemed to be. No thorough study of the phenomena of variability had been made, and it was simply assumed that the diversity of forms within the cultivated races was due to one cause only. This was indicated by the well-known expression that no two individuals of a race are exactly alike. All specimens differ from one another in their industrial qualities as well as in their botanical characters. These qualities and characters are inheritable and the offspring of a selected individual will vary, according to Vilmorin, around an average lying between the type of the original species and that of the chosen individual. By this means the range of variability will be extended in the desired direction, and this may be repeated during a number of years, until the industrial value of the new race clearly surpasses that of the old one.

Evidently, it was said, natural selection must work in the same way. But the question remains whether this will really lead to new species, or only to local and temporary adaptations.

The answer to this question has been given by the newest discoveries of agricultural practice itself. Hjalmar Nilsson, the director of the celebrated experimental station of Svalöf in Sweden, discovered that variability among cultivated plants is not a single phenomenon, but contains at least two widely contrasted features.

He found that, apart from fluctuating variability, every cultivated species is a mixture of elementary types. A field of a cereal is only apparently uniform, and a closer investigation soon reveals numerous differences in the height of the stems, in the time of flowering, in the size and almost all other qualities of the ears, in resistance to diseases, and especially in the industrial value of the grains. Moreover, he found that all these qualities are strictly inheritable. Nilsson took the grains of a single ear and found that all the individuals issuing from them are strictly alike and carefully repeat the characters of their mother. From such a chosen ear one may derive by repeated sowings grain enough to sow a whole field, and this will show an almost complete and very striking uniformity. Therefore our ordinary species and varieties of cultivated plants are in reality mixtures of a smaller or larger number of different races, which grow together, but are, as a matter of fact, independent of one another. These races themselves are almost invariable, but their mixture in the field produces upon us the impression of a great variability.

What is the significance of this discovery for the explanation of artificial selection? Evidently this will tend to isolate the better races of the mixture and to exclude those of average or low value. Two methods may be followed: Either the breeder collects a handful of ears chosen with the utmost care from all parts of his field and secures a lot of grains large enough to sow a parcel of a moderate extent, or he limits his choice to one ear only, which will take him one year more to obtain the necessary quantity of grains. The first method is the one which is still commonly followed, the second was introduced some twenty years ago by Nilsson.

The real nature of the first method may be explained by means of the careful studies of Rimpau, who applied it for the improvement of his rye. The group of ears of the first choice will evidently be itself a mixture, although of a lesser number of types. In choosing year after year a handful of the best ears Rimpau must gradually have purified this mixture, until after twenty years he succeeded completely in isolating the very best one of them. From this time his race must have been pure and constant, no further selection being possible. Using the method of Nilsson, the same result may be reached by a single choice, and therefore in one year. The new race is produced by a jump and not by the slow and gradual improvement, by small and almost invisible steps, which was assumed by Rimpau and Darwin.

From these discoveries the question arises, whether natural selection also proceeds by jumps and leaps, and not, as was commonly assumed, by imperceptible steps? The answer may be deduced from the observations of Jordan and others on the existence of elementary species in nature. Almost every wild species consists of some of them, and in special cases their number increases so as to embrace dozens or even hundreds of sharply distinguished types. Sometimes these are found in widely distant stations; at other times, however, they are growing in mixtures. Natural selection will, of course, under changed conditions, simply multiply one or two of the types to the exclusion of the others. As a whole, the species will make progress in the desired direction, but in reality there will be no change of forms.

From all these and many other considerations it follows that the basis, which the practice of artificial selection seemed to afford to the theory of natural selection, is a fallacious one, and that the idea of evolution by means of slow and almost imperceptible steps must therefore be abandoned. But if this is conceded, how are species really produced in nature?

The theory of mutations answers that species are produced by means of jumps and leaps, exactly in the same way as varieties in horticulture. Varieties are only beginning species, says Darwin, and the same laws must govern the origin of both of them. Now, in horticulture, it is well known that varieties usually arise at once. In a field of a species with blue or red flowers some day an individual with white flowers is seen. Ordinarily it is only one, and it is not surrounded by transitions or by flowers of intermediate colors. Sometimes there may be two or three, but then their flowers are of the same degree of whiteness. One seed of the species has been transformed into a variety, and this is its whole origin. A single season suffices to produce the effect, no slow and gradual improvement being required. Moreover, the seeds of the first individual, if fertilized and saved separately, will reproduce the variety wholly pure. The same rule prevails for large groups of other cases; everywhere varieties arise by jumps, requiring only one year for their arrival.

The same rule also holds good in nature. But in order to show this, direct experiments are required. For this object I have cultivated a large number of wild species in my experiment garden, trying to see them produce varieties, and to be enabled thereby to study the laws of this process. Let me adduce two instances, the origin of the peloriated toadflax, and that of the double variety of the corn marigold. These varieties appeared in my cultures all of a sudden, after a number of years, the one in about half a dozen of individuals in successive generations, the other in a single instance. The ordinary toadflax has only one spur on its flowers and remained so in hundreds of individuals until a single specimen bore five spurs on every one of its flowers. The corn marigold had normal flower heads until 1899, when one individual produced some slight signs of duplication. Next year all its descendants bore double flowers and the race showed itself constant from the very beginning.

Thus the production of varieties by leaps and jumps may be considered as a well-proved fact in horticulture, and in a state of nature. It is a firm basis for a new theory, and is readily understood, as we have only to transport the principle from the varieties to the origin of elementary species. Recognized for species, the theory will obviously be true for genera and families also, and explain the evolution of all organic

* From an address delivered at the University of Brussels, January 17th, 1914.

[1] "The Mutation Myth" is the title of a recent article in *Science*, N. S., vol. xxxix, No. 1005, April 3rd, 1914, p. 488, its author, Edward C. Jeffrey, starts from the conception that the mutation theory has been derived from my experiments with *Œnothera Lamarckiana* and allied species. This opinion is indeed, even yet, not unfrequently held by those who have not read my books. It is obviously erroneous and therefore may well be called a myth. Logically and historically the desirability of those experiments has been derived from the theory, as will be seen in the text. Jeffrey bases his arguments upon the well-known researches of Geerts concerning the partial sterility of many of the members of the natural family of the *Onagraceæ*. Geerts found that in almost all the genera of this family, including all their species as far as investigated, the ovules are for one half in a rudimentary condition, which excludes the possibility of their being fertilized, while about one half of the pollen grains is sterile. This double character has therefore persisted during the pedigree-evolution of almost this whole family. In contradiction with Geerts, Jeffrey considers it to be an indication of a hybrid condition. If this were true, almost the whole natural family of the *Onagraceæ* would have evolved in a hybrid condition and *Œnothera Lamarckiana* would follow the rule. It remains doubtful, however, how this hypothesis could explain the high degree of mutability of *O. Lamarckiana*, since the majority of the supposed hybrid species do not show signs of such a condition.

beings in all the different lines of the genealogical tree.

The idea of the origin of species by leaps and jumps has the great advantage of answering in an unexpected and decisive way the numerous and, in part, very grave objections which have been brought forward against the theory of Darwin. To my mind, this is one of the best arguments in its favor. It releases the theory of evolution from the serious difficulties which its adversaries have never ceased to urge against it. Therefore it seems useful to give a brief survey of them now.

The oldest and most serious objection is based on the obvious uselessness of new characters during the first stages of their evolution, if this is supposed to be invisibly slow. Imperceptible odors cannot guide insects in their visits to flowers and assure to these a sufficient advantage in the struggle for life. Adaptations for the capturing of insects by plants would be of no value in a primary and imperfect condition, and therefore cannot be evolved by the action of natural selection. Imperfect instincts would be rather obnoxious, according to Wasmann, and thus would be liable to be destroyed instead of increased by this action. So it is in many other cases. Beginning characters would always be too insignificant to be of any value in the struggle for life. Evidently the principle of leaps and jumps at once relieves us of the necessity of this hypothesis. It does not admit a gradual appearance of characters, but assumes these to appear at once in the full display of their development, and without the aid of natural selection.

The same holds good for useless characters. The theory of Darwin cannot explain them. According to him, every quality is developed exactly through its utility, and useless properties should be eliminated from the very beginning by the struggle for life. But it is now generally recognized that many beautiful differentiations are in reality no adaptations at all, and that their usefulness is at least very doubtful. This, for instance, is the case of heterostyly and of the likeness of the flowers of some orchids to insects. The theory of mutations has no difficulty with useless, and even with slightly prejudicial characters. Arising by a sudden jump, they may keep their place, provided only that they are not in such a degree hurtful as to prevent a normal development of the individuals.

A third objection has been derived from the studies of the celebrated anthropologist Quetelet, who discovered the general law of fluctuating variability. He introduced the principle of studying every quality for itself and of comparing the different degrees of its development in a large number of individuals. He found by this means that characters simply follow the laws of probability. They vary around an average condition in two directions, of increase and decrease, but precisely thereby this variability excludes the production of a new character. Darwin tried to derive the one from the other, while the theory of mutations recognizes the almost diametrically opposed nature of the two phenomena.

A last objection has been brought forward by the study of the age of the earth. Physicists as well as astronomers have refused to accept the theory of slow evolution, as the time required by Darwin in connection with his ideas seemed by far too long. A man's life would not suffice to see the changes, which, after him, would be necessary to produce a single step in the line of evolution. The differentiation of a flower or of a seed would require millions of years if it went on so slowly, and the development of the whole organism of a plant, and still more so that of the higher animals, would obviously require a vastly larger amount of time. Darwin has calculated the necessary time for the evolution of the whole animal and plant kingdom on the assumption of slow and almost imperceptible changes, and estimated it to be at least equal to some thousands of millions of years.

But our globe cannot be as old as that. There is quite a large number of arguments which allow us to estimate the age of the earth with a sufficient degree of accuracy, and they all point, unanimously, to a period of only some twenty or forty millions of years. This number is evidently far too small for the explanation given by Darwin, and in consequence thereof it has always been considered as one of the most decisive arguments against the theory of slow and gradual evolution.

In order to estimate the age of the earth different phenomena may be used. First the separation of the moon, secondly the solidification of the earth's crust, then the condensation of the aqueous vapor and the formation of oceans. The quantity of salt dissolved in these oceans and the thickness of the geological layers, especially those of a calcareous nature, afford further arguments.

According to George Darwin, the moon was separated from our globe about fifty-six millions of years ago. The age of the solid crust has been calculated by Lord Kelvin from the increase of the temperature in deep mines. In some regions the temperature is seen to increase about one degree for every fifty meters; in others, however, one degree for a hundred meters. On the average the considerations of Lord Kelvin gave an age of twenty to forty millions of years for the solid crust of the earth.

The quantity of salt obviously increases in the oceans on account of the salt added by the rivers and of the evaporation of the water. The total quantity of this salt has been calculated and the quantities of the yearly supply of water are known for all the larger streams, as well as their percentage of salt. From these data we may calculate the annual increase of salt in the oceans and find how many years would be required for our present rivers to accumulate all the salt now found in the seas. According to Joly, about ninety millions of years would be necessary. But obviously the rivers must exhaust the grounds which they drain, and formerly these must therefore have been much richer in salts. This consideration must lead us to diminish the number of years required in a very sensible manner.

The age of the geological strata has been deduced from their thickness and the velocity of the process of sedimentation. Sollas estimates the total thickness at about eighty kilometers and the average rate of deposition of the layers at 30 centimeters per century. From these numbers we may find an age of twenty-six millions of years for the collective deposition of all the geological layers. Calcareous rocks have been built by organisms and mainly by corals and mollusks. These have made use of the lime added to the sea by the rivers. Dubois has calculated on the one hand the whole thickness of these rocks, and on the other the yearly supply of lime from the rivers. He concludes that thirty-six to forty-five millions of years would be required to produce the whole of this system.

All these data have been subjected to a criticism by Sollas and compared with one another. Obviously the highest estimates are only limits, and in considering this Sollas arrives at the general average of about twenty to forty millions of years. He points out that the epochs which have served as starting points are not very far distant from one another, considered in a geological way, and that therefore they may be taken together to delineate the duration of organic life on this earth.

As we have seen, this duration is by far too short to allow the slow and gradual development of life supposed by Darwin. It necessitates a very substantial abbreviation of this process, and thus affords one of the best supports of the theory of mutations.

Thus we see that this theory is based on almost all the branches of natural science. All of them join in the assertion that the hypothesis of slow and almost invisible changes is too improbable to be accepted, and is even in open contradiction to some of the best results of other sciences. The theory of an evolution by leaps and jumps evades all these objections, and thereby releases the theory of Darwin from its separate position.

But it is doing more than this. By rejecting the hypothesis of invisible changes it leads us to search for the visible alterations, which it assumes to be the leaps and jumps by which animal and vegetable species are being produced. If the transformation of one species into another is a visible process it must evidently be sought for and be brought to light in order to study its laws, and to derive from this study an experimental proof for the theory of evolution.

However, it is hardly probable that these jumps are numerous in nature as it now surrounds us. On the contrary, they must rather be rare, since nobody had seen them until now in the field. Therefore I have sought for a plant which would produce more of such mutations than other plants. I have studied over a hundred species, investigating their progeny, and among them one has answered my hopes. This is the evening primrose of Lamarck, which chances to bear the name of the founder of the theory of evolution which it is prepared to support. It is a species which grew wild in the territory of the United States, where it has been collected by the well-known traveler and botanist Michaux, and whence Lamarck derived the authentic specimen for his description. Since that time it has spread in Europe and is now found especially in England, Belgium, and Holland in a number of localities, some of which consist of many thousands of individuals. In more than one of these localities it has been observed to produce mutations, especially in a field near Hilversum in Holland, whence I have obtained the individuals and seeds which have served as the starting points of my cultures.

In these cultures the species is seen to be very pure and uniform in the large majority of its offspring, but to produce on an average one or two aberrant forms in every hundred of its seedlings. The differences are easily seen even in young plants, and are mostly large enough to constitute new races. The more common ones of these races are produced repeatedly, from the seed from the wild plants as well as in the pure lines of my cultures. It is obviously a constant and inheritable condition which is the cause of these numerous and repeated jumps.

These jumps at once constitute constant and ordinarily uniform races, which differ from the original type either by regressive characters or in a progressive way. By means of isolation and artificial fecundation these races are easily kept pure during their succeeding generations.

I shall not insist here upon their special characters. The most frequent form is that of the dwarfs, *Œnothera nanella*, and the rarest is the giant, or *O. gigas*, which has a double number of chromosomes in its nuclei (28 instead of 14), and by this mark and its behavior in crossing proves to be a progressive mutation. Other new types which are produced yearly are *O. rubrinervis*, *O. Oblonga*, and *O. albida*. *O lata* is a female form, producing only sterile pollen in its anthers, and *O. scintillans* is in a splitting condition, returning every year in a greater or less number of individuals to the original type from which it started. Besides these there are a large number of mutations of minor importance, many of which have not even been described up to the present time.

Thus we see that the experiments provide us with a direct proof for the theory of evolution. They constitute an essential support of the views of Darwin, and moreover they relieve them of the many objections we have quoted, and bring them into harmony with the results of the other natural sciences.

But, besides this, they show us the way into a vast new domain of investigation and afford the material for a study of the internal and external causes which determine the production of new species, at least in those cases in which, as in the primroses, mutations are relatively abundant. From these we may confidently hope to come some day to the study of those rarer mutations on which the differentiation of the main lines of organic evolution seems to have depended.

An Idiot's New Brain

At the last meeting of the Paris Academy, Dr. Serge Voronoff read a remarkable paper on the operation performed by him at the Clinique Sainte Marguerite, near Nice, in the course of which he gave to the world the first news of a fresh scientific miracle; in fact, a sort of supermiracle, as it consists of nothing less than inoculating a cretinous youth, alias an idiot, with something taken from a monkey, and—*mirabile dictu!*—improving the intelligence of the boy.

The miracle is stupendous in every way as to the result announced, but how a mere layman is to explain it is the difficulty. I confess that I do not understand myself the processes of the operation, and I must leave it to scientific experts to correct any involuntary mistakes which a layman may make. The boy was 14 years of age. He had been normal up to the age of 8, when he had an attack of scarlatina, following which all the characteristic accidents of cretinism were developed. His skin became yellow and pink and scaly and dry. His hair became scarce and brittle, his eyelids swollen, his nose flattened, his cheeks flabby, his whole face bloated. The eye was dull, and the expression of his face idiotic.

Six months ago Dr. Voronoff grafted the right lobe of the thyroid gland of a baboon on the lower part of the boy's cerebral organ. The effect was both immediate and progressive. Day by day the child's mental and physical condition improved. His face lost its sickly color and its flattened appearance. The child's growth, which had been checked, began again, and has since continued normally. His mental improvement was still more remarkable. The boy, who before had been dull and obtuse, and had taken no interest in his surroundings, in his lessons, or in his companions, surprised his schoolmaster by becoming alert, bright, and finally even mischievous. He is now keen alike in the school and in the playground. Dr. Voronoff explains that the cretinous disposition is brought about by the absence of the secretions produced by the thyroid gland. The difference between an intelligent man and an imbecile, he says, does not depend altogether on the development of the brain, which may be the same in both, but on the secretions of this gland, which have a particular effect on the intellectual activity of the cerebral matter. Give an imbecile a thyroid gland in good working order, and he will display the keen intelligence which he actually possessed, but which remained inert because his brain did not receive the necessary stimulus.—*The Daily Telegraph.*

The Ancon Meteorological Observatory, in the Canal Zone, is about to be installed in the new administration building at that place. An 80-foot steel tower is being erected to support the anemometer, wind-vane and sunshine-recorder. A seismograph will be installed in the basement of the administration building.

Producer Gas for Industrial Purposes*

Economy and Convenience Where Both Power and Heat Are Required

By Thomas Wilson

WITHIN the last few years the use of gas for heating purposes in many industries has greatly increased. Cleanliness and convenience and the ease with which it can be controlled so that the temperature can be closely regulated have been the deciding factors. Natural and city gas have been used to good advantage, but for low-temperature work up to 2,000 deg. Fahr. anthracite producer gas has given equal satisfaction at a much lower cost. The cost item has induced manufacturers to install gas producers using inferior grades of anthracite to supply gas, not only for heating purposes, but for power.

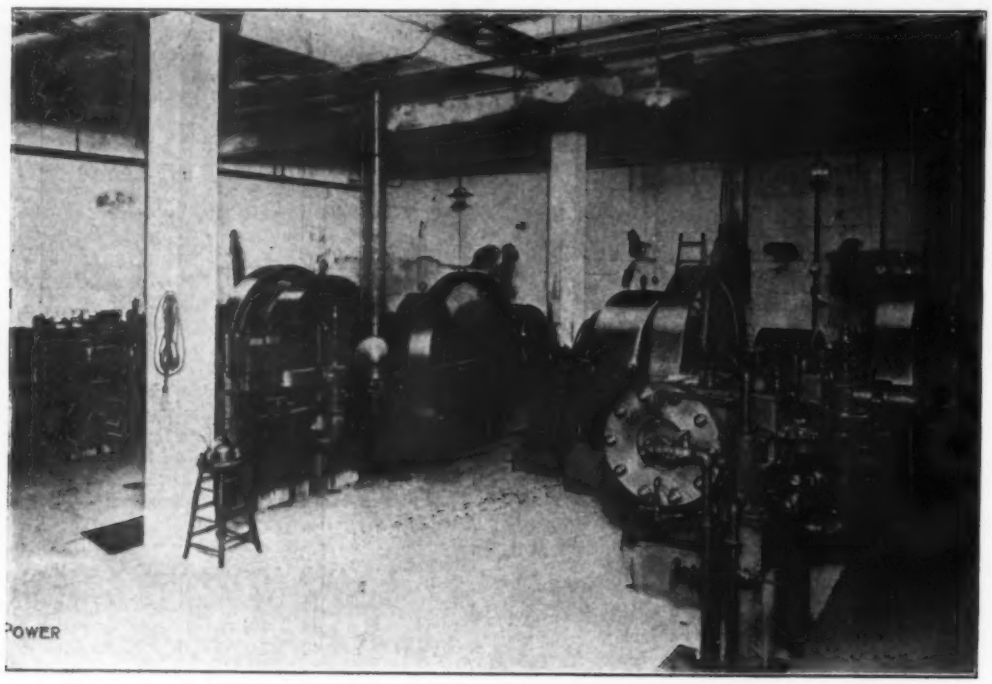


Fig. 1.—Gas-engine plant at Barnhart Brothers & Spindler.

A plant involving this double service has been installed in the new factory of Barnhart Brothers & Spindler, Chicago, makers of type and printers' supplies. The gas is used for melting the metal in type-casting machines, for hardening furnaces, machine torches, brazing torches, for lead and slug casting, in annealers, copper- and nickel-plating baths, etc. About 70 per cent is required for these purposes and the balance by the engine units generating current for power and lighting.

There are 70 type-casting machines, each equipped with individual motors. All chases are electrically welded, for which fully 75 horse-power is required. A machine shop in which the factory machines are made and repaired takes considerable power; besides, there are electrically driven pumps and fans, and an elevator and conveying machinery to move the product in the course of manufacture. When the plant is running to full capacity, with the chase department in operation, the load will average close to 150 kilowatts, and when chases are not being welded it will drop off one third. Consequently, two units have been installed, one a 125 horse-power, 17¼ by 16-inch, four-stroke-cycle tandem gas engine directly connected to a 75-kilowatt direct-current generator, and the other a twin engine of the same type and size of cylinders driving a 150-kilowatt generator; the speed in each case is 250 revolutions per minute. These machines are operated 10 hours a day, and it is the plan to use them alternately, depending on the welding periods. The plant also has a breakdown service; but so far it has been called on only for night lighting, for the fire pumps and for starting the blower, run in connection with the two producers of 350 horse-power each.

As the plant has been running only a short time no satisfactory records are available, but it may be said that the gas, which averages about 145 and has reached 151 British thermal units per cubic foot, has given excellent satisfaction both for heating and power purposes. About 95 pounds of buckwheat No. 1 in the producer is equivalent to 1,000 cubic feet of natural gas containing 800 British thermal units per cubic foot, and 75 pounds is equivalent to the same quantity of city gas containing 550 to 600 British thermal units. At $5 per ton, which is a high charge for such coal in quantities, the fuel cost would be 24 and 19 cents, respectively. To this must be added the labor item and the interest and depreciation on the producer installation; even then the total cost does not exceed much more than one third the usual charge for city gas. In a preliminary estimate, the equivalent of 1,000 cubic feet of city gas was figured to cost 31.3 cents, including a charge for water and interest and depreciation amounting to 16 per cent. For the engines the guarantee was 1⅛ pound of buckwheat No. 1 per brake horse-power-hour at full load, which at $5 per ton gives a fuel charge of 0.28 cent. This amount will generate about 79 cubic feet of producer gas, and with a heat content of 145 British thermal units will supply 11,455 British thermal units per boiler horse-power-hour.

THE PRODUCER PLANT.

In this department each of the two Flinn & Dreffein units is rated at 350 horse-power and consists of a producer and an economizer; a scrubber serves the two generators. The producers, of the water-sealed type, have a heavy steel shell 8 feet in diameter by 12 feet high, firebrick lined, and rest on legs in a concrete pan. The fuel is supported on a layer of ashes on the bottom of the pan. Between the bottoms of the shell and the pan there is a clearance of 12 inches, and as the pan diameter is greater than that of the shell, there is room for removing the ashes, which are placed in 400-pound cans, hoisted to the street level and carted away.

Coal from a 100-ton bunker below the street level is delivered by gravity through a chute into the bucket of a 1-ton electric monorail hoist, which for feeding can be moved directly over the hopper of each producer. At their rated load the two require 750 pounds of coal per hour, although they are now running at only two thirds capacity. The producers are not charged heavily, but are fed uniformly with 150-pound charges at 35-minute intervals. The hoist bucket easily holds ten charges, and is usually filled four times each day.

The coal enters the producer through a double-seal hopper, a counter-weighted bell at the bottom of the hopper preventing the admission of air while the coal is being fed. The sliding plate at the top is closed while the bell is lowered, so that the coal may run down over it and be evenly distributed over the fuel bed. The hopper rests on a water-cooled top having poke holes for attending to the fuel bed.

A feature of the producer is the annular tuyere of dog-house cross-section, which uniformly distributes the air and steam to the fuel bed. This construction facilitates the ash removal, as the ashes can drop around or within the annulus and easily reach the concrete pan at the bottom.

An important part of the plant is the economizer, which in the present installation is 9 feet high and 42 inches diameter, and consists of two concentric steel shells forming two chambers. The gas from the generator passes through the inner one and gives up part of its heat to the air flowing in the opposite direction through the outer chamber to the fuel bed. Ordinarily the gas leaves the producer at 1,200 deg. Fahr., and if it passed directly to the scrubber it would carry about 12 per cent of the heat in the coal. By raising the temperature of the air to 500 degrees in the economizer, two thirds of this heat is reclaimed.

In the pipe connection between the top of the outer chamber and the tuyere of the producer, a steam blower is inserted to saturate the air and equalize the pressure in the top of the producer; otherwise, there would be a slight depression caused by the suction of the engines and of the blower supplying the shop equipment. Atmospheric pressure is thus maintained so that there is no tendency for air to be drawn in or gas to be blown out through the poke-holes when attending the fuel bed.

With the air at this high temperature, combustion is facilitated and the steam is carried to the fuel bed without condensation; it is also claimed that a richer gas is thereby obtained. The steam is supplied by a small vertical fire-tube boiler rated at 15 horse-power and having a pressure of 50 to 80 pounds, depending on the load the producers are carrying. The quantity of steam is controlled by a gasometer connected by block-and-tackle to a weighted lever attached to the stem of the balanced steam valve. The gasometer connects with the top of the producer. As the load increases, the gas pressure tends to drop, so that the gasometer lowers slightly, and, through the connecting links, increases the opening of the steam valve. A drop in load produces the reverse results.

From the economizer to the wet scrubber the gas passes through a three-way water-sealed valve from the top of which the purge pipe leads to the roof. Water-sealing the valve eliminates any possible trouble from tar and soot sticking to a dry seat and makes the tightness of the valve more certain. The scrubber serving the two units is 6 feet 6 inches in diameter by 22 feet high, and contains a coke column supported on trays, water sprinklers above, and at the top a layer of excelsior to remove the moisture.

From the scrubber the gas is drawn directly to the engines by the suction of the pistons. As for industrial purposes, it is necessary to supply the gas at a definite and uniform pressure; there is an exhauster belt driven

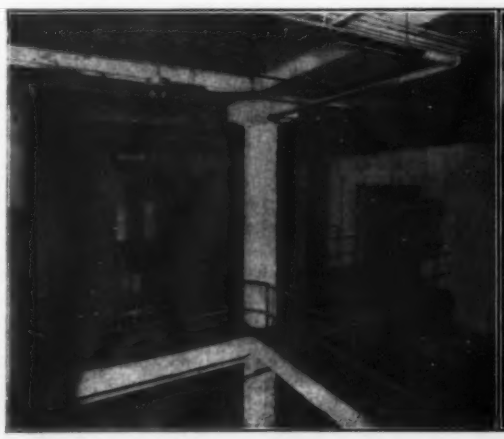


Fig. 2.—Charging floor of producers.

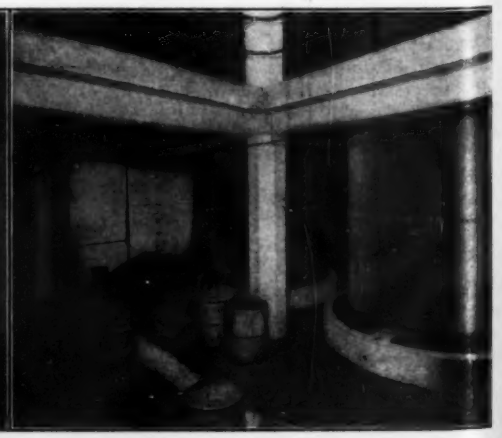


Fig. 3.—Bottom of generators and steam boilers.

* Reproduced from *Power*.

by a 15 horse-power motor. Instead of using a gas holder, a pipe connection is made between the delivery and suction sides of the exhauster. In this line is a back-pressure valve weighted for the desired pressure; when this exceeds the predetermined value, the valve opens and returns part of the gas to the suction side of the exhauster. The latter is run at constant speed so that the maximum output will be available. To the valve spindle is attached a diaphragm subject to the pressure in the gas main, and opposing this are weights on the upper side of the diaphragm. The construction is such that the diaphragm casing may be rotated at will, pulling with it the valve disk and thus keeping it free from soot or deposit by the grinding action on the seat.

For the engines, the gas is clean enough as it comes from the wet scrubber, but for small burner work it must also be passed through a static washer operating on the impact principle. The washer, Fig. 6, consists of a chamber having two compartments, the upper one giving space for gas admission and a spray of water. Hanging from the dividing wall is a threaded cylinder with a piston having threads of the same pitch, but not in contact with those of the cylinder wall. Both are so tapered that as the piston is moved downward the flow area is lessened and the velocity of the gas is increased, or *vice versa*. The stem attached to the piston has threads of the same pitch also, so that in moving the piston up or down there is no variation in the "mesh."

In passing through this zigzag course, the remaining soot particles in the gas are deposited on the metal surfaces and washed down through the drain at the bottom of the lower compartment. The purified gas passes on to the burners.

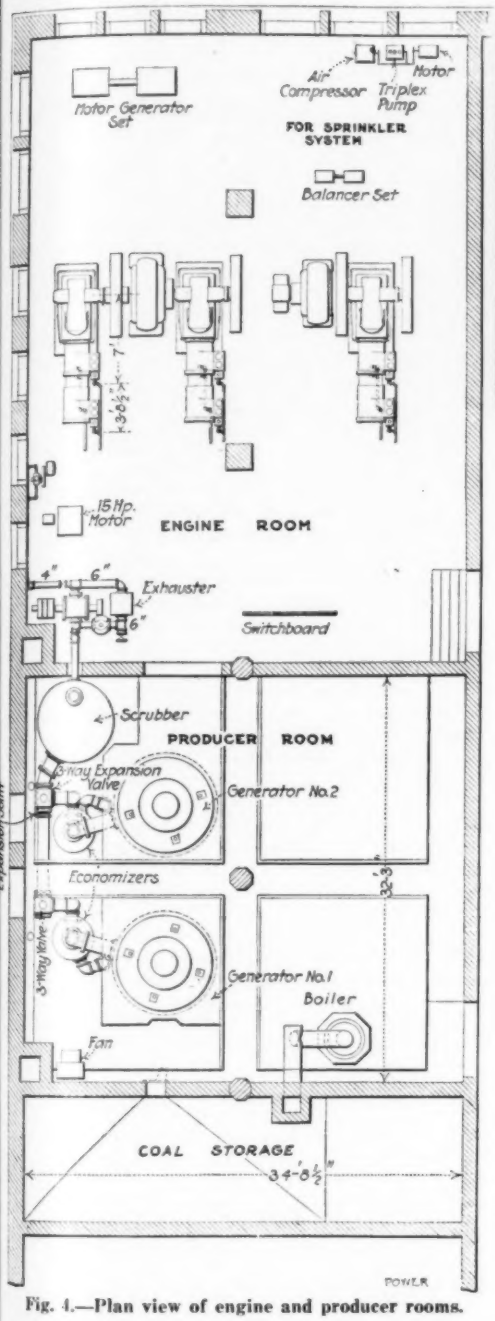


Fig. 4.—Plan view of engine and producer rooms.

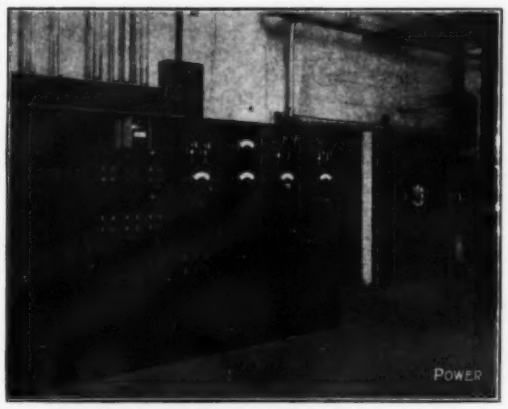


Fig. 5.—Switchboard, static washer, and exhauster.

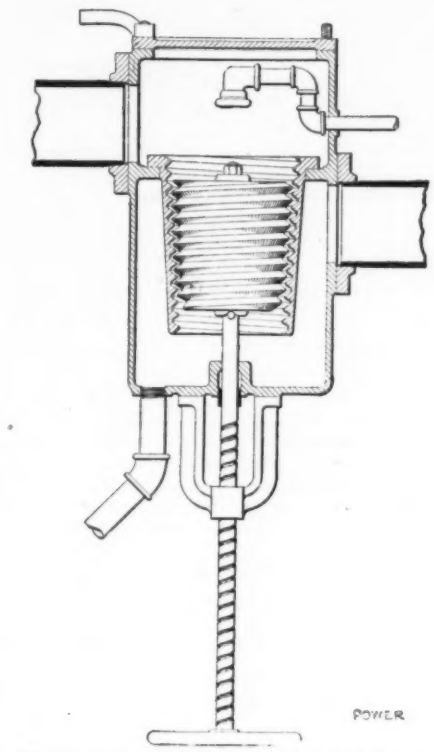


Fig. 6.—Sectional view through static washer.

ENGINE ROOM.

The engines are of the tandem type directly connected to 110-, 220-volt, three-wire generators, with a balancer set. Rites inertia governors acting through balanced cut-off valves control the speed, and under the severe conditions imposed by the welding department they have maintained close regulation.

The plant is distinctive in design in that any part of either engine, with the exception of the crankshafts and flywheels, is interchangeable, and either half of the twin engine can be run independently of the other. In this way, one tandem unit can be out of service and the other two will be available to furnish the maximum load of 150 kilowatts.

A 10-inch pipe from the scrubber, with 6-inch taps to each tandem unit, supplies the gas to the engines. From the twin engine, two 6-inch exhaust pipes discharge to a 12-inch muffler; this reduces to 8 inches as it leads to the roof. The single tandem engine has a 6-inch exhaust, a 10-inch muffler and a 6-inch riser.

Air for starting is stored in two 30-cubic foot tanks at 200 pounds pressure during the day by a motor-driven compressor. From a 5,000-gallon tank on the roof, cooling water flows through the engine jackets and then to the suction of a 2-inch motor-driven centrifugal pump which returns it to the tank through a cooling tower above the tank. In case of accident to the pump, city water will be used temporarily.

Other equipment includes a pump and air-compressor unit for the sprinkler system, a motor-generator set to supply current of the proper voltage for welding, two bilge pumps to raise the sewage to the necessary level, and a triplex pump to circulate water through the type-casting machines.

For heating the building, two water-tube boilers, each able to serve 10,000 square feet of radiation, supply steam at a 5-pound pressure to a vacuum system having 16,000 square feet of radiation. A steam plant was first considered, but because of the low efficiency in summer, of insufficient exhaust steam to supply the heating for at least part of the winter, and because gas was needed in the shop, the present plant appeared to be the best; considering its brief period of operation, nothing has happened to gainsay this decision. The gas for both services has given satisfaction, and, from the meager data available, the cost has been exceptionally low.

Amputations Less Frequent in War

INTERESTING figures of the cost of medical service in war and the percentages of death from wounds in modern warfare are given in an editorial in the *New York Medical Journal*. The *Journal* quotes Prof. Charles Richet of the University of Paris as authority for the assertion that ambulance service alone for 500,000 wounded or ill costs $1 a day for each, or $500,000.

"This is a startling sum," says the editorial, "but apparently it does not take into consideration the cost of feeding the doctors, nurses, and either chauffeurs, or drivers of horses connected with the ambulance service, while there is no estimate of the first cost of the elaborate paraphernalia, drugs, apparatus, instruments, etc., required."

Roughly speaking, the editorial asserts, battle casualties in recent wars have varied from 10 per cent to 20 per cent of the number of soldiers engaged. The ratio of killed and wounded has been about one to four. Of the casualties, from 65 to 80 per cent were caused by rifle fire and from 20 to 30 per cent by artillery fire, chiefly shrapnel. Bayonet and saber wounds have been of comparatively infrequent occurrence, and little mention is made of them in reports. In the civil war in this country 90 per cent of the total wounds recorded were caused by small arms, while the injuries from artillery amounted to only 9.87 per cent of the total wounds.

"The increase in range, the rapidity and accuracy of fire developed in modern military firearms, supplemented by the relative increase in the strength of field artillery, will have an important bearing upon the character of the wounds and the number of the casualties," say the *Journal* in commenting on the present war. "Experience in recent wars has demonstrated the character of the injuries produced by modern firearms. The European powers have all adopted rifles with similar ballistic properties. The bullet is jacketed, of small caliber, varying from 6.5 millimeters to 8 millimeters, and weighs from 150 to 200 grains. It is either ogival or pointed in shape and has an initial velocity of from 2,000 to 2,700 feet a second.

"The pointed or 'spitz ball' has been adopted by England, Germany, Turkey, and the United States. The wounds inflicted are, therefore, entirely different from those inflicted by the rifle in use several decades ago. This weapon had a low velocity and carried a soft leaden bullet of large caliber.

"Experiences in the Russo-Japanese and Balkan wars have demonstrated that at the greater ranges perforations of the abdomen, chest, and skull may take place with astonishingly slight effects. This statement must be modified so far as the pointed bullet is concerned, since this bullet has its center of gravity near its base, and is usually 'set up' on meeting with slight resistance, thus forcing its way through the tissues in its length instead of in its diameter.

"Fatal primary hemorrhage occurs much more frequently than in earlier wars, because the small-caliber jacketed bullet is more likely to sever vessels, while the large-caliber bullet, moving with less velocity, affords time for the blood vessel to be pushed aside from its course.

"It has been estimated that 85 per cent of deaths on the modern battlefield are due to hemorrhage. Secondary hemorrhage, which in former wars was of such common occurrence, nowadays rarely occurs, while traumatic aneurism is much more frequent.

"Amputations are much less frequently necessary, and then only where there is extensive destruction of limb, as in wounds by large shell fragments, or injuries to blood vessels completely arresting circulation. Wounds inflicted by the modern rifle bullet, if properly protected against infection, never require amputation unless the circulation is arrested. Machine guns use the rifle ammunition, and the wounds inflicted by them are identical in character with those inflicted by other small arms.

"The wounds inflicted by shrapnel differ from those caused by the rifle bullet in that they are accompanied by a greater contusion and involve a greater amount of tissue, shrapnel bullets being of greater size and having a much lower velocity. Shrapnel wounds are frequently multiple, and almost invariably suppurate, since they are very apt to carry foreign material from the clothing into the wound."

The Flying Machine from an Engineering Standpoint—IV*

A Review of Recent Progress

By Frederick William Lanchester, M. Inst., C.E.

Continued from SCIENTIFIC AMERICAN SUPPLEMENT No. 2016, Page 127, August 22, 1914

7. *Motive Power Installation.*—We are now faced with the consideration of the motive power installation. At the present time the internal-combustion engine—more definitely the gasoline motor—holds the field. No other prime mover is able to compete, either on the score of weight per horse-power or fuel-weight economy; there is nothing in sight likely to oust the internal-combustion motor from its supreme position.

The relative importance of lightness and economy of fuel is determined by the class of service for which the motor is required. In Fig. 27 curves are given of weight/horse-power for various motors; ordinates represent weight of motor plus fuel, abscissæ the duration of the run at full load. It can be seen at a glance from this diagram that for brief periods the weight per horse-power of the engine is the all-important factor, whereas for long runs this becomes relatively less important, the weight of gasoline and lubricating oil becoming the main item. On referring to Fig. 27, it will be noted, taking the extremes, that the Gnôme engine starts with a very considerable advantage over

Fig. 27.

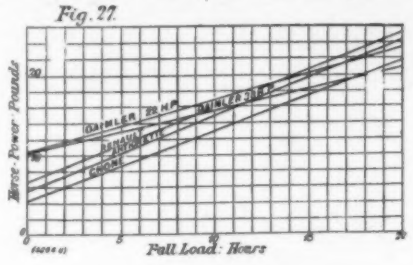


Fig. 28.

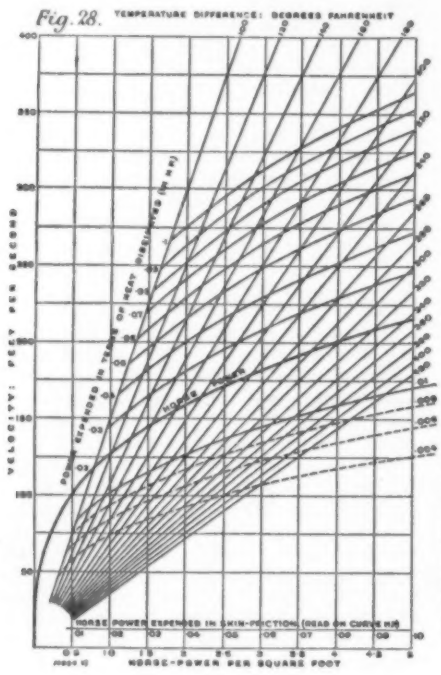

TEMPERATURE DIFFERENCE: DEGREES FAHRENHEIT
VELOCITY: FEET PER SECOND
HORSE-POWER PER SQUARE FOOT
HORSE POWER EXPENDED IN SKIN-FRICTION (READ ON CURVE m)

Fig. 29.

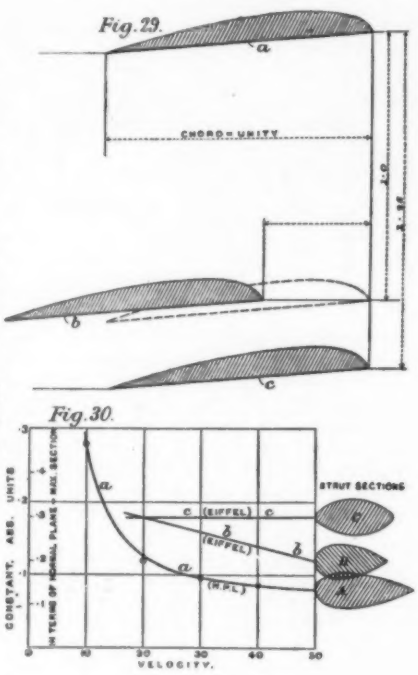
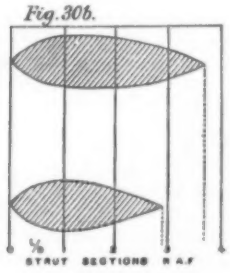


Fig. 30.

Fig. 30b.



the motor-car engine given for comparison, but after a run of 17 hours at full load, the motor-car engine (represented for the purpose of illustration by the Daimler) by its greater economy has taken the lead. This diagram was prepared by me some three or four years ago (see Report of the Advisory Committee for Aeronautics for 1909-10). Many of the aeronautical motors of the present day combine with a weight/horse-power factor of about 4, a degree of economy that compares well with the best automobile practice.

Out of the great multiplicity of types of aeronautical engine now on the market there are two types, namely, the rotating engine on the one hand and the light-weight multi-cylinder V type on the other, which I consider likely to survive. The rotating type of engine gives the possibility of very complete balance with simplicity of working parts, and so provides the aeronautical constructor with an engine especially serviceable where small machines are concerned, and simplicity and upkeep[28] are of importance. The rotating engine is, at the present day, reasonably economical in gasoline, but is grossly extravagant in lubricating oil, and consequently is at a disadvantage for long-distance work; it will, however, probably hold its own for some time to come in machines for short-distance flying. The rotating engine, also, suffers from some disadvantages on the score of exhaust silencing. The multi-cylinder V type, though ordinarily not so light, power for power, as the rotating engine, has many advantages, especially for high power and where long distances have to be negotiated.

It is customary in the rotating engine to employ direct air-cooling; it is, in fact, difficult to arrange such an engine with water-cooling. The horse-power absorbed in the Gnôme engine incidental to air-cooling is very great; in the original so-called 50 horse-power Gnôme (which actually gives very little over 40 horse-power in flight), the power consumed in wind resistance, even on the test stand, amounts to something nearly 6 horse-power, and it may be materially greater under flying conditions.

In engines of the V type, water-cooling is in greater favor; the Renault special aeronautical motor is an exception, being cooled by air-blast generated by a centrifugal fan. The weight of the water-cooling system when fitted amounts at the best to 0.6 pound per horse-power (with water nearly 1 pound per horse-power), and thus constitutes a serious addition to the weight of the installation. Here, again, the class of service becomes important. It is evident that for short-distance flying, where engine-weight is of paramount importance, it may be better to employ direct air-cooling; when, however, a long-distance service is required, it may arise that the weight of the water-cooling system is justified by the saving in horse-power and better fuel consumption.

According to a recent investigation by me[27] the minimum horse-power expended in cooling, that is to say, the horse-power necessarily expended in cooling, is a function of the area and temperature difference of the surface exposed, and there is some difficulty in providing an air-cooled engine cylinder with sufficient gill surface to keep the horse-power loss as low as desirable; when on the other hand water is used as a heat carrier, the rigid limitation as to available surface no longer applies, there is some disadvantage, however, as to temperature difference. In Fig. 28 a diagram is given showing the essential relations between horse-power, equivalent of heat dissipated per square foot surface (abscissæ), tangential velocity of air (ordinates), temperature difference, and power absorbed in skin friction. It will be understood the graphs represent the minimum horse-power absorbed, based on the assumption that the air is traversing the surface along a stream-line path, and that there is no additional loss of power in eddy-making (other than that incidental to skin friction); the honeycomb type of radiator most nearly complies with this condition.

We may now proceed to consider the interrelation and compatibility of engine and propeller. It has already been pointed out that in order to get the full output from a given engine (as is also well known to be the case in marine propulsion), a propeller pitch has often to be selected far from that proper to highest efficiency. The difficulty has (as in the early Wright machine) been met by adopting a reduction gear; alternatively (as also in the Wright machine) a multiplicity of propellers may be employed. It is evident, for example, that, if four propellers be used in place of one propeller, the individual diameter may be halved, and consequently for a given pitch (and therefore revolution speed) the pitch diameter ratio doubled. The original Wright machine furnished a good example of a case in which the propeller pitch diameter ratio was made approximately that of best efficiency, and this result was obtained, in spite of the low velocity of the Wright machine, by a combination of both methods; that is to say, two propellers were used instead of one, and these propellers were geared down from the engine in the relation 10 to 33.

The incompatibility at present existing between the engine speed and the propeller pitch becomes less as the flight velocity is increased, so that, in the case of an ordinary machine of about 1,400 pounds total weight, the propeller speed (for best efficiency) for a single-screw machine becomes appropriate to the normal engine speed at about 100 miles per hour. Since the loss of efficiency for a fine-pitch propeller, even down to half the pitch ratio of best efficiency, is not great, it may be taken that for flight speeds of 50 miles an hour upward, the balance of advantage lies definitely with the direct-coupled propeller; this agrees with experience. A point of interest in connection with propellers of comparatively fine pitch and somewhat reduced diameter, such as commonly in use to-day, is the fact that, with the engine opened fully out, there is very little difference between the thrust and the revolution speed, whether the machine is standing or in full flight—it is commonly reported that the revolution speed does not increase more than 10 per cent from "standing" to full normal flight speed—the thrust variation also is slight. This fact constitutes the only justification for the static test of aeronautical propellers, frequently resorted to when approximate data are required. There is no doubt that in a propeller of theoretically perfect proportion, or in an existing propeller, if fitted to a machine of less resistance, there would be a far greater response to flight speed variations. Actually, this is a case in marine propulsion where the propeller revolution recorder is commonly found to give more reliable readings than the ship's log.

8. *Relating to the Design of the Aerofoil.*—We shall now proceed to the discussion of the more detailed arrangements and structural features of the machine. First, the aerofoil. The pressure appropriate to least resistance we have already seen to be given by the expression[29] $0.32\ \rho\ V^3$ in absolute units, or $\frac{\rho V^3}{100}$ in pounds

* The James Forrest lecture, delivered before the Institution of Civil Engineers on May 5th. Compare also the same author's paper on "Catastrophic Instability in Aeroplanes," SCIENTIFIC AMERICAN SUPPLEMENT, February 14th, 1914, p. 98.

[28] With the rotating engine in its present state of development the question of upkeep is not its most satisfactory feature.

[27] Report of the Advisory Committee for Aeronautics, 1912-13, page 94.

[29] Compare Figs. 17 and 18 and text. The constant 0.32 is empirical.

per square foot. Consequently if w is the weight (in flying order) the area required is $\frac{100\,w}{\rho\,V^2}$ as appropriate to least resistance.

The above is the whole basis of any initial "lay out"; there are many refinements, however, to be considered, which enter into the complete problem; the principal of these are:

The fact that part of w is a function of the aerofoil area—the quantity we are determining—means that the best area will be less than given by the foregoing expression. This point has been dealt with by me in "Aerial Flight," 1907,[20] vol. 1, §§ 171, 194, 195, 196; also more recently by the staff of the National Physical Laboratory.[20]

Beyond the above, the specification of flight velocity for any machine consists more often than not in the prescription of higher and lower limits rather than of a set fixed speed. Under these circumstances, the final values and proportions are based on a lay-out of graphs of resistances, thrust, etc., on the lines of the diagrams already given, Figs. 11 and 12.

It is evident from the general character of the resistance velocity curve, as shown diagrammatically in Figs. 11 and 12, that whereas considerable departure may be permitted from the normal velocity of flight on either side of the minimum without incurring appreciable increase in resistance, at the limits of the flight-speed range, the slope of the resistance curve is considerable, and there will be sharply defined points at which the resistance is equal to the maximum propeller thrust, and no liberties can be taken. It is important to note that at the maximum limit of flight speed the equilibrium of thrust and resistance is stable, whereas at the minimum limit the conditions are those of instability, so that should the machine at any time fall below the minimum, the aeronaut can only recover his power of flight by calling upon gravity to assist him—that is to say, by taking a downward course. If, as when near to the ground (or an obstacle), the downward course is not permissible, the machine will execute an undignified descent, to which the verb "to pancake" has been applied. The critical speed at which this will take place is not necessarily related to the critical "least velocity" angle of the aerofoil.

Briefly, for a given machine the extent of the flight-speed variation is a function of the reserve of thrust over the minimum resistance value, the absolute value of the limits being fixed by the load that the aerofoil is called upon to sustain. In the case of a high-powered machine, however, the lower limit may be prescribed by the critical angle of the aerofoil.

The choice between monoplane and biplane is, in the main, a question of constructional engineering; there is not a great deal to choose between the two from an aero-dynamic standpoint, but with equally good design the monoplane gives a slightly better lift/drift ratio. The interference effect of the two members of a biplane aerofoil has been studied by many investigators. Langley showed, about 1890, that with superposed planes (aspect ratio = 4) the interference was not serious when separated by a distance equal to their lesser dimension. The results of a more recent investigation by the staff of the National Physical Laboratory are published in the report of the Advisory Committee for Aeronautics for the year 1911-12 (page 73), from which Table IX has been taken. In addition to obtaining

TABLE IX.—*Table of Multiplying Factors to Obtain Coefficients from the Coefficients for a Single Aerofoil.*

Biplane Spacing, Gap/Chord.	Lift Coefficient.			Lift/Drift.		
	6 Deg.	8 Deg.	10 Deg.	6 Deg.	8 Deg.	10 Deg.
0.4	0.61	0.62	0.63	0.75	0.81	0.84
0.8	0.76	0.77	0.78	0.79	0.82	0.86
1.0	0.81	0.82	0.82	0.81	0.84	0.87
1.2	0.86	0.86	0.87	0.84	0.85	0.88
1.6	0.89	0.89	0.90	0.88	0.89	0.91

quantitative data for the particular aerofoil chosen (Blériot, aspect ratio = 4), an investigation was also made on the effect of staggering the planes. It is shown to be advantageous to arrange the upper foil in advance of the lower; thus the combination *a b*, Fig. 29, is of the same efficiency as the combination *a c*.

Considering the aerofoil, whether monoplane or biplane, from a structural standpoint, and in investigating the strength of the aerofoil as a whole, it may be treated definitely as an inverted cantilever system. Thus, comparing the stresses in an aeroplane to the stresses in a cantilever bridge, we have the weight of the fuselage with its alighting chassis, motor, passengers, etc., the inverted equivalent of the supporting reaction on the central pier of a cantilever girder. We have the air-pressure force, by which the said load is sustained, distributed along the aerofoil length corresponding to the weights of the outstanding members of the cantilever. We have a variation of pressure from point to point due to gusts, eddies, etc., corresponding to some degree to the movable loads representing traffic over the bridge. In the case of the aerofoil we have in addition something not represented in the analogy of the cantilever girder, i. e., the weight of the aerofoil itself directly supported by the pressure reaction; we may, however, regard this equal and opposite distribution of weight and pressure as superposed on the main system, and as not contributing to the stresses in the aerofoil members. So far as the analogy to the bridge holds goods, it is evident we have a well-known engineering problem which is capable of being treated by well-known methods. In the calculation of stresses of the aerofoil members two alternative methods are in current use; in the one the aerofoil struts are treated as pin-jointed members, by the usual truss-girder construction; according to the other method, in place of the hypothesis of the pin-joint, we have the hypothesis of continuity in the main longitudinals. The first and simpler method has been used by several firms for many years past, and gives results, which, under ordinary conditions, are very much on the safe side; the second method has been developed during the last few years by the National Physical Laboratory,[21] and has been adopted by the Royal Aircraft Factory, and more recently by other manufacturers.

On the pin-joint hypothesis the stresses are solved by the well-known graphic stress diagram; the alternative method is considerably more complex; reference should be made to the report cited. It is well to remark that though the pin-joint hypothesis gives results usually on the safe side, the extent of the factor of safety so introduced is not one that can be relied upon, and may in special cases be even negative. It is hardly necessary to point out that the more important and vital the problem, the less appropriate become methods of an approximate and inexact character.

9. *Resistance of Struts, Wires, Wheels, Etc.*—The question of the resistance of components, such as are commonly embodied in the design of existing machines, has been studied experimentally at the National Physical Laboratory, at the Aerodynamic Laboratory at Göttingen, and by Mr. F. Eiffel, in Paris. A few results relating to strut sections are given in Fig. 30. The graph *a a* is a plotting from National Physical Laboratory data,[22] relating to the sections *a*, representing one of the best forms tested; graphs *b* and *c* relating to sections *b* and *c* as determined by Mr. Eiffel.[23] In Fig. 30 ordinates represent resistance coefficient in absolute units, also in terms of normal plane (the normal plane unit being that of maximum section). In Fig. 30*b* are given two strut sections designed at the Royal Aircraft Factory. These were reported upon by the National Physical Laboratory as giving less resistance for given strength than a number of others submitted. Approximately, strength for strength, these sections gave one fourth the resistance of struts of circular form.[24]

The resistance of wires and ropes has been investigated both by the National Physical Laboratory and by Prof. Prandtl of Göttingen; the position may here be summarized by saying that the resistance of a rope or stranded cable, at right angles to the direction of motion, is virtually equal to that of its projected area in normal plane. The resistance of smooth wires is about 20 per cent less. Both these results only hold good above a certain minimum value of $l\,V$, which may be taken at about 1.5, thus at 100 feet per second the rule may be taken as applying to cables or wires down to about three sixteenths inch (= 0.015 foot diameter).[25]

Another interesting set of determinations, for which we are indebted to the National Physical Laboratory, is that relating to the resistance of alighting wheels; these have been tested both in respect of resistance and lateral reaction.[26] The direct resistance of a 26-inch wheel fitted with a 2½-inch pneumatic tire appears to be equal to about a third of its projected area in terms of equivalent normal plane, the projected area being taken to be that of the tire itself. For fuller information reference should be made to the memorandum cited.

10. *Vertical Surface.*—One of the quantities of great importance in connection with the type of stability known as rotative or spiral stability is that of vertical surface. It is of great importance to be able to compute with accuracy the effective distribution of vertical surface in any machine, and of recent years considerable attention has been devoted to, what we may term, the "valuation" of accidental vertical surface. For example, every vertical or inclined strut has a certain directive value, which may be expressed in terms of vertical surface; the alighting wheels, especially if of disk form, represent considerable areas of the equivalent vertical surface; even the fuselage (the stream-line body or car) has its equivalent value as vertical surface. It was pointed out by me some years ago[27] that a screw-propeller moving other than axially experiences a considerable lateral force. More recently Mr. T. W. R. Clarke has called attention to this action, and to the importance of considering the propeller in its capacity as effective vertical surface. It appears from Mr. Clarke's investigation[28] that the propeller equivalent in terms of vertical surface is a very large and serious factor, and one that under no circumstances should be ignored. The memorandum in question is worthy of careful consideration by all engaged in the design or construction of flying machines.

A point that should not be overlooked is that the propeller value in the sense under discussion is totally different when under power and when dragging or stationary; this suggests the desirability of locating the propeller as near to the center of gravity (in the fore-and-aft sense) of the machine as conveniently possible.

11. *The Dynamic Load Factor and Factor of Safety.*—A matter of importance, and one of a controversial nature, is the factor of safety necessary in order to take care of the many and varied conditions met with by a machine in flight. In the simple case of a machine in horizontal flight in calm weather we know that the load supported by the aerofoil is the weight of the body of the machine and its associated parts, but not including the aerofoil itself, whose weight is directly distributed over the pressure surface; also we know that in the various evolutions a machine is called upon to perform, the stresses may considerably exceed the normal, and that variations of effective load are experienced, due to wind-gusts, which it is quite out of the power of the pilot to prevent. Excluding for the time being the latter, we are clearly able to define the worst that the pilot is able to do and specify the factor by which the normal stresses must be multiplied in order to represent the actual stresses; conversely, we may specify arbitrarily a factor of safety, and we may tell the pilot just what he is permitted to do, and just what he cannot undertake without risk. Taking, in the first instance, the assumption that the pilot is allowed to do his worst—he is to be allowed to try to wreck his machine. There are two ways in which he can operate; first, he can drive his machine at the highest possible speed and suddenly alter his elevator to the position corresponding to the lowest possible speed; alternatively he may take sharp turns involving heavy banking. Now the highest possible speed is the limiting velocity which the machine will acquire falling head first vertically; this, with machines as at the present day constructed, may be estimated at about 140 to 150 miles an hour. The lowest velocity in the present sense is the velocity at which the aerofoil is meeting the air at its critical angle (the lowest velocity capable of giving a pressure reaction equal to the weight); this may be taken for our purpose as 40 miles an hour. If, when falling vertically at 140 miles an hour, the pilot with absolute suddenness jerks his elevator into position corresponding to 40 miles an hour, the reaction brought to bear on his aerofoil is $\left(\frac{140}{40}\right)^2 W$, that is to say, approximately twelve times the weight of the machine. In practice, for the figures given the maximum load would be diminished, since the elevator cannot be moved with absolute suddenness, and, if it were, the machine could not answer the elevator and alter its attitude to the line of flight immediately. It is probable, on the basis of the figures given, that 10 W is the maximum effective load that could under any circumstances be brought to bear.

In the case of severe banking, if the machine be banked to an angle θ, the resultant of the weight and centrifugal force is the value $W \sec \theta$. I have frequently made estimates of the angle of banking when a pilot has been making a steep spiral dive; the angle rarely exceeds 60 degrees or 70 degrees. Taking 70 degrees as the maximum, the stresses in the machine will correspond to a load equal to 3 W.

From the foregoing it would appear almost certain that in calm weather the pilot, if asked to do his worst, cannot in any manner reach or exceed ten times the stresses due to the static load.

Let us take what may be considered an extreme gust.

[20] Constable & Co.

[21] Report of the Advisory Committee for Aeronautics, 1911–12, page 78.

[21] Report of the Advisory Committee for Aeronautics, 1912–13, No. 83.

[22] *Ibid.*, 1912–13, page 111.

[23] "Resistance of the Air and Aviation," page 184.

[24] Report of the Advisory Committee for Aeronautics, 1911–12, page 96.

[25] Compare Memoranda 40 and 75, Reports of the Advisory Committee for Aeronautics.

[26] Memorandum 74, Report of the Advisory Committee for Aeronautics, 1912–13.

[27] *Engineering*, February 26th, 1909.

[28] Presented to the Advisory Committee by Mr. Mervyn O'Gorman. Memorandum 80, March, 1913. Report, 1912–13.

The machine enters air, or is struck by a gust represented by a change of velocity equal to half the flight-speed. Assuming the machine has time to swing to its appropriate relative direction under the new conditions, a simple resolution of velocity shows that the worse condition is that in which the direction of motion of the gust is directly opposed to that of flight; in such a case the relative velocity of the machine becomes 1½ times normal, and the effective load on the aerofoil will be $(1\frac{1}{2})^2 = 2\frac{1}{4}$ times normal. In case of the machine being struck by a sudden gust or squall, the load will be considerably higher, but still does not approach the figure 10 obtained on the basis of the pilot suddenly "flattening out" when at maximum speed.

It is evident from the foregoing that a flying machine in the course of its normal usage is liable to stresses many times greater than that of its normal load, and the frequency of these stresses, and the total number of times they occur in the life of the machine, will be related to their magnitude by some empirical law for any given class of service. In such a case it is evident that the term "factor of safety" does not carry its ordinary meaning; if, for example, in the lifetime of a fleet of 100 machines the stresses reach six times normal once, and five times normal, say, ten times, and four times normal, say, 150 times, it will be certainly sufficient and proper if the designer works to six times the normal load for his elastic limit without using any factor of safety in the accepted sense at all; to do otherwise would be to burden the whole 100 machines with a weight of superfluous material without justification. Whether under these conditions we continue to employ the term "factor of safety" or not[39] the aeronautical designer must bear clearly in mind that in his particular case his factor has a double function, namely, both to give the margin of strength and durability needed under ordinary conditions of flight, and to provide for abnormal conditions of stress, occasionally, even almost to the theoretical limit of the strength of the structure.

In Memorandum No. 96 of the Advisory Committee (not yet included in an annual report) the matter is fully considered, and the extreme probable values are estimated as follows:

Nature of Contingency.	Computed Dynamic Load-factor.
Gusts	4.0
Banking	1.4
Flattening out	8.0
Looping[40]	4 to 5

In the report in question[41] the recommendation is made that a factor N be adopted in design not less than 5 or 6, this being considered sufficient to take care of anything likely to happen to a machine with reasonable and proper pilotage. Tests and calculations of the wing-spars of different existing machines gave the following results:

Type.	Value of N.	How Determined.
A	4	By experiment.
B	4	Do.
C	5	By calculation.
D	3	Do.
E	3	Do.
F	4	By experiment.
G	7	By calculation.

The Royal Aircraft Factory have adopted a factor somewhat greater than that recommended in the Memorandum in question; a machine (G in above table), of which the aerofoil was tested to destruction, actually recorded 8.4.

In connection with the subject of aerofoil structure it is to be observed that the stress distribution varies considerably under different conditions, namely, at different angles of attack. Referring to Fig. 15, it will be noted that the aerofoil structure commonly includes two longitudinal members, front and rear, respectively, and the proportions of the load borne by each depends upon the position of the center of pressure and varies with its displacement, which can only be ascertained from experiments on a scale model of the aerofoil itself. This fact needs consideration when computing the maximum stresses on the members in question and the aerofoil structure as a whole.[42]

The calculation of the aerofoil structure not only comprises the resolution of the main lifting-force distribution, as already discussed, but also entails the calculation of the longitudinal stresses due to line-of-flight, or "drift" forces. These may be quite moderate under normal flight conditions, but may become far more severe at abnormally high speeds.[43] The treatment of this problem does not offer any serious difficulty; it is to-day generally considered the best practice to provide for the edgewise strength of the wing by its own internal diagonal bracing.

(To be concluded.)

[39] This point may perhaps be emphasized by the use of some qualified expression such as "dynamic load-factor."

[40] Estimated by me; not in original report. The basis of this estimate is the phugoid chart, Fig. 1*a*; the dynamic load-factor is given by the height H in terms of H_n, or in the case of looped paths numbered 8 to 12 the value of $\frac{H}{H_n}$ varies from 3.6 to 5.5.

[41] If this factor N cannot with propriety be termed a factor of safety, I suggest the term "factor of contingency"—i. e., the factor of contingency requires to be the equal or greater than the dynamic load-factor for which it makes provision.

[42] Reference should be made to the Report 96 cited.

[43] When a machine is diving head first downward at or near its limiting velocity the drift load is considerably greater than half the weight of the machine.

The Darwinian Theory Denied*

In the course of his opening address at the meeting of the British Association for the Advancement of Science, at Melbourne, Australia, on the 14th, Prof. William Bateson, the president of the association, discussed the theories of Darwin, and his conclusions controverted the generally accepted theories of evolution. His address was, in part, as follows:

"We must begin seriously to consider whether the course of evolution can at all reasonably be represented as an unpacking of an original complex, which contained within itself the whole range of diversity which living things present.

"As we have got to recognize that there has been an evolution, that somehow or other the forms of life have arisen from fewer forms, we may as well see whether we are limited to the old view that evolutionary progress is from the simple to the complex, and whether, after all, it is conceivable that the process was the other way about. When the facts of genetic discovery become familiarly known to biologists and cease to be the preoccupation of a few, as they still are, many and long discussions must inevitably arise on the question, and I offer these remarks to prepare the ground.

"I ask you simply to open your minds to this possibility. It involves a certain effort. We have to reverse our habitual modes of thought. At first it may seem rank absurdity to suppose that the primordial form or forms of protoplasm could have contained complexity enough to produce the divers types of life. But is it easier to imagine that these powers could have been conveyed by extrinsic additions? Of what nature could these additions be? Additions of material cannot surely be in question. That which is conferred in variation must rather itself be a change, not of material, but of arrangement or of motion.

"The invocation of additions extrinsic to the organism does not seriously help us to imagine how the power to change can be conferred, and if it proves that hope in that direction must be abandoned, I think we lose very little. By the rearrangement of a very moderate number of things we soon reach a number of possibilities practically infinite.

"That primordial life may have been of small dimensions need not disturb us. Quantity is of no account in these considerations. Shakespeare once existed as a speck of protoplasm not so big as a small pin's head. To this nothing was added that would not equally well have served to build up a baboon or a rat."

Prof. Bateson pointed out that a great body of experiments, made and making according to the method laid down by Mendel, tended toward the theory that variation is produced by a loss of normal qualities. "I have confidence," he said, "that the artistic gifts of mankind will prove to be due not to something added to the make-up of an ordinary man, but to the absence of factors which in the normal person inhibit the development of these gifts. They are almost beyond doubt to be looked upon as 'releases' of powers normally suppressed. The instrument is there, but it is 'stopped down.'" He added:

"As the evidence stands at present, all that can be safely added in amplification of the evolutionary creed may be summed up in the statement that variation occurs as a definite event, often producing a sensibly discontinuous result; that the succession of varieties comes to pass by the elevation and establishment of sporadic groups of individuals owing their origin to such isolated events, and that the change which we see as a nascent variation is often, perhaps always, one of loss.

"Modern research lends not the smallest encouragement or sanction to the view that gradual evolution occurs by the transformation of masses of individuals, though that fancy has fixed itself upon popular imagination. The great advances of science are made like those of evolution, not by imperceptible mass improvement, but by the sporadic birth of penetrative genius. The journeymen follow after him, widening and clearing up, as we are doing along the track that Mendel found."

Not only did Prof. Bateson reverse the current notion of evolution, but he said that natural evolution accounted scarcely at all for the diversity of species; that the doctrine of the survival of the fittest was undeniable so long as it was applied to the organism as a whole, but that Mendelism had shown that in its application to the parts, to details of specific differences to the spots of the peacock's tail, to the coloring of an orchid flower—details in which the potency of natural selection had been urged with the strongest emphasis—it was quite untrue. While favored races survived, that truism "scarcely at all accounts for the diversity of species."

He declared that he could not disguise his sympathy with the effort of the Mendelian extremist Lotsy that all variation might be due to crossing. He added that without experimental breeding it was certain that "we are merely guessing when we profess to distinguish specific limits and to declare that this is a species and that a variety. The only definable unit in classification is the form springing from similar germ cells which breeds true."

* The Address of President Bateson, of the British Association for the Advancement of Science, at Melbourne.

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